EVALUATION OF NEW TECHNOLOGIES FOR CLEANUP OF PRODUCED OILY SOLIDS FROM HEAVY OIL OPERATIONS

FINAL REPORT

SUBMITTED TO

PROJECT STEERING COMMITTEE

CANADIAN PETROLEUM ASSOCIATION

CPA CONTRACT NO.: AFE 89-6205-036

MONENCO PROJECT NO.: CPA 8601-2/5893

Monenco Consultants Limited
400 Monenco Place
801 - 6th Avenue S.W.
Calgary, Alberta
T2P 3W3

July, 1990

CANADIAN PETROLEUM ASSOCIATION

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Monenco
Engineering a whole new world.

1990-07-25
CPA 8601-2

Mr. F.C.K. Chan
Chairman - Project Steering Committee
Canadian Petroleum Association
c/o Amoco Canada
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P.O. Box 200, Station M
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Dear Frank:

Subject: Evaluation of New Technologies for Cleanup of Produced Oily Solids from Heavy Oil Operations
CPA File: APE 89-6205-036

Monenco Consultants Limited is pleased to submit the enclosed Final Report in seven copies, to the Project Steering Committee, Canadian Petroleum Association. In accordance with the agreed scope of work defined with the Task Force of PSC earlier this year, a separate copy of Appendix E: Technology Master File is also included herein.

It has been a very fruitful endeavor of working on this significant environmental project. We believe that a comprehensive information base, containing

- produced oily solids data,
- current process technology capability & costs, and
- immediate field assessment programs,

has been established, enabling CPA to proceed with Phase II and Phase III of the Project in the near future.

Monenco appreciates being given the opportunity of working for you and the PSC members of CPA. We look forward to continuing our services for Phase II and Phase III of the Project.

Yours very truly,

Frank H. Wu

for L.A. Panek
Vice President, Environmental Division

LAP:mvw
Encl.

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ACKNOWLEDGEMENTS

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The principal members of both teams are herein acknowledged:

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This Report presents the work done under the auspice of the Project Steering Committee (PSC) of Canadian Petroleum Association (CPA). The reference CPA file number is: AFE 89-6205-036. A separate binder, entitled Appendix E: Technology Master File, forms an integral part of the Report.

In the early stage of the Project, Monenco Consultants Limited and its subcontractor Raymond Mineral Dressing worked closely with PSC to define the scope of work. The term "Oily Solids" was also defined (Section III). The approach and tasks were established such that:

- processable reservoir-originated produced oily sands and sludge generated and stored in the production facilities are the subject materials to be cleaned up;
- emphasis is to be placed on processability when assessing oily solid information;
- wide-spectrum of technologies are to be solicited;
- technologies selection is to be based on "cradle-to-grave" criteria;
- along with Esso's Road Application, three selected technologies are to be subject of detailed evaluation; and
- field assessment programs will include costs, scope and schedule estimate.

The above are described in more detail in the first two sections I and II.

An "Invitation Package" was prepared, approved and mailed to the prospective technology owners or representatives. Simultaneously, a national advertisement campaign for open solicitation of technology proponents was made. The result was a gratifying response: over 45 submissions! Excluding the "fringe technologies" and the irrelevant ones, a total of 34 technologies was enlisted in the pool for preliminary assessment and selection. Appendix E: Technology Master File (separate volume) compiles the core technical information of the relevant technologies.

Parallel to the acquisition and assessment of technology information, data of produced oily solids from Alberta and Saskatachewan heavy oil operators was collated, evaluated and characterized. This is addressed in Section III. In brief, there are wide variation in oily solids quality:

- Oil and grease: 4 - 15%
- Water phase : 5 - 12%
- Solid :70 - 90%

and in production rates ranging from less than 1 m^3/h to about 10 m^3/h from Sask-Alta Cooperative, collectively.

A Kepner-Tregoe decision analysis session was held with the attending PSC members as voting participants. Three technologies which have demonstrated a high degree of potential for meeting the crade-to-grave requirements, cost-effectively, were selected for further evaluation:

- ASTCO's STS Hotwater Extraction;
- Pacific Environment's Fluid Bed Combustor; and
- Halliburton Hydraulic Fracturing Sand Reinjection.

Several well-proven technologies, noteworthy being the AOSTRA Taciuk Processor (ATP), were not in the group of the selected processes. However, it is recommended that ATP be used as the base process technology for the future Phase III Field Assessment Program. Esso's Road Application technology was, as stated earlier, selected as the base technology for cost comparison. Section IV details the individual technologies in six generic classes, the assessment process and concluding remarks on Kepner-Tregoe analysis.

Further requests for detailed and definitive technical, cost and field testing information were forwarded to the companies representing the selected technologies. Meetings with the company representatives were held. A very comprehensive "Cradle-to-Grave" technical and cost evaluation was made, as presented in Section V, resulting in the following estimated costs:

- STS Hotwater Extraction: $\$107/m^3$
- Fluid Bed Combustor: $\$105/m^3$
- Halliburton Sand Reinjection: $\$136/m^3$
- Esso's Road Application: $\$ 75/m^3$

Scope, cost and schedule for field assessment programs were formulated and are described in depth in Section VI. Due to the nature of the technologies, capability of the proponents and availability of ready-made test facilities, the programs vary widely in scope, cost and schedule. However, all the necessary information, such as requirements, test parameters, field test unit sizes, program management and so on, has been covered extensively in this report.

Several conclusions and recommendations were made, as presented in Section VII. In summary they are:

- Technologies are available for cradle-to-grave cleanup and disposal of produced oily solids.

- Field testing to evaluate viability and for process optimization and scale-up would be required of
  - STS Hotwater Extraction and
  - Fluid Bed Combustor

- At the current regulatory permitting conditions, Halliburton's Sand Reinjection represents the best cradle-to-grave option (albeit higher cost), while Esso Road Application was complimented on its cost effectiveness and effective utilization of resources - derived materials, i.e. the produced oily solids.

SECTION I

INTRODUCTION

SECTION I

INTRODUCTION

With the depletion of conventional oil production in Western Canada, heavy oil has become a major source of crude. Majority of heavy oil is produced by injecting steam into the oil bearing formations to reduce viscosity of the crude to the point where it can be pumped to the surface. Along with the crude, sand is produced at the wellhead and must be disposed of. In addition, the well sites and processing facilities produce other oily solids which are amenable to cleanup in the same manner as the wellhead oily sands. In seeking an alternative to road application and with the increasing needs of oily wastes disposal, the Canadian Petroleum Association (CPA) decided to contract the study on processes and technologies which could be effective to cleanup and dispose of oily solids.

The approach agreed to, in cooperation with CPA, was to solicit technologies from various proponents, and select the most promising new processes which would allow "cradle-to-grave" clean up and disposal of the produced oily solids. Field testing programs would be outlined which would allow field testing to confirm the viability of the selected processes. The scope and terms of reference for testing would then be prepared.

SECTION II

SCOPE OF WORK

SECTION II

SCOPE OF WORK

Evaluation of oily solids cleanup technologies was set up in three phases with an ultimate objective of determining a proven process or processes which could be economically adapted to the heavy oil operations. The first phase of the work which is dealt with in this report has the following specific objectives:

- o produced oily solids data acquisition, characterization and evaluation;
- o establishment of project and technology evaluation database;
- o solicit, screen and evaluate cleanup technologies and technology proponents - defining, on a preliminary basis, current technological capability; and
- o formulate a Phase II and Phase III program for the selected technologies with a realistic scope and terms of reference for the Phase III field demonstration and assessment.

1 INFORMATION GATHERING

Some of the oily solids production and inventory data for this study had already been compiled in previous CPA reports. The data was updated and collated, and the "gaps" were filled with information solicited from the various heavy oil operators.

The source, quantity and characteristics of the various waste types would be defined in as much detail as was required to

identify the spectrum of feed specifications that these "new technologies" could be expected to process. The geographic distribution of oily solids was assessed to determine the suitability of large scale regional cleanup facilities, smaller facilities at individual production operations or mobile facilities. Based on the above information, a test location would be selected.

In addition, a request was submitted to various proponents of "new technologies" as well as advertisements in order to ensure that all of the entrepreneurs with oily solids cleanup experience could participate in the evaluation.

2 SCREEN AND RECOMMEND TECHNOLOGIES FOR FIELD ASSESSMENT

The primary objective of this portion of the work was to identify and evaluate available technologies. Criteria were established for technology screening, and a joint Kepner-Tregoe analysis was performed to identify the most promising emerging technologies. Technology capability and constraints were then evaluated within the battery limits of the plant. Options for regional sites or sites associated with existing plants were then evaluated. Utilities and offsite support requirements were established at the process battery limits. Mini-economic evaluations were performed in order to finalize the assessment. It was important that the total waste disposal system be considered including the following:

- o transportation, storage and handling prior to treatment;
- o treatment process and related utility system requirements such as power, fuel, water and chemicals;

- handling, storage and transportation after treatment;
- disposal methods for all waste streams from the process.

Some assumptions were made about the nature and scale of the facilities in order to prepare these estimates. In addition, the disposal methods anticipated for the different waste streams were evaluated based on environmental suitability.

3 SCOPE DEFINITION OF FIELD ASSESSMENT PROGRAM

The scope of Phase II and Phase III was formulated in sufficient detail to enable a "terms of reference" to be defined for the Field Assessment Program. In addition, a request was submitted to various proponents of "new technologies" as well as advertisements in order to ensure that all of the entrepreneurs with oily solids cleanup experience could participate in the evaluation.

4 REPORTING

Progress reports were issued periodically and at the conclusion of a major task. Additionally, when the various technologies were summarized, a milestone report was presented to the Project Steering Committee (PSC) and a Kepner-Tregoe analysis followed. A subsequent presentation towards the end of the project, but prior to the final report, was made in order to ensure that the contents of the final report would be acceptable to the PSC.

SECTION III

CHARACTERIZATION OF THE OILY SOLIDS

SECTION III

CHARACTERIZATION OF THE OILY SOLIDS

The following section describes the oily solid byproducts associated with the heavy oil operations in Peace River, Ft. McMurray, Cold Lake, Lloydminster and Kindersley areas. The major producers of oily solids are Shell Canada Resources Limited in Peace River, Esso Resources Canada Limited at Cold Lake and the Sask-Alta Waste Disposal Cooperative* in Lloydminster. The Canadian Petroleum Association provided the definition of oily solids as studied herein, and a request for information (outlined in Section III, 2.) was sent to its members.

1 DEFINITION OF PRODUCED OILY SOLIDS

For this study, Produced Oily Solids was defined at the December 21, 1989 meeting by PSC as:

> "Solids produced as a by-product of heavy oil production (i.e. reservoir originated solids which include sand, fines, silt, etc.) but excluding spill and reclamation material."

To effectively address the main objective of evaluating processes/technologies for cleaning up the materials, such wastes as spent filters, rags, hay bails and debris which cannot generally be processed in continuous operating plants have not been considered in this report.

---

*Sask-Alta Cooperative is a collection of many heavy oil operators covering a vast geographical area of approximately 55 000 Km^2.

More specifically, the oily solids and sludges considered include oil spill recovered (excluding vegetation and logs) from heavy oil processing plants and well sites; tank bottoms and dewaxing line wastes; produced oily sands from wells and heavy oil processing plants; and well site solids contaminated during operations. Much of this material is collected in in-plant storage pits at Peace River and Cold Lake. The "Ecology Pit" as commonly referred to is essentially a lined oily wastes collection or temporary storage pit. These oily solids constitute, by far, the greatest quantity of wastes associated with heavy oil operations.

2 DATA SOURCING AND INTERPRETATION

In order to establish the quantity and quality of oily solids and their locations, a letter requesting specific information was sent to the sixteen major producers of heavy oil. Combined, these operators represent over 90% of heavy oil production. The letter is attached in Appendix A.

3 CHARACTERIZATION

Oily solids are a complex mixture of produced heavy oils associated with formation sands and saline water derived from heavy oil production. The oil phase consists of high viscosity bitumen with about 15-20% aromatics including hazardous organics such as benzenes. In the case of produced sands the oil phase is within a water phase and the solids are mostly water wet. The freshly produced oil droplets are relatively larger so that the oil emulsion is easily broken with mild agitation. The residual oil or the produced sands is the finer material which requires more vigorous agitation or coalescence followed by a separation process in order to be recovered. The longer the sands are stored, such as the

Ecology Pit oily solids, the greater the chances are that the solid particulates will become oil wet, thereby requiring very vigorous processing (high energy input) to render the oil feasible for recovery. Similarly, slop oils, tank bottoms, sludges and spills are a much more difficult emulsion to treat and therefore require higher energy processes.

The aqueous phase is highly saline, with a chloride content ranging up to 60 000 mg/L, and in general not acceptable for surface disposal. It must be reintroduced into the plants and disposed of in deeper saline formations or impounded in impervious containment areas. Further treatment is required for disposal in water ways on surface.

The solid phase of produced oily solids is generally a graded sand (relatively coarse) with some small quantities of clay. Since clays have a large ion exchange capacity (lower for kaolinite to very high for smectite), light hydrocarbons (particularly solvents and naphtha) and salts collect at their interlayers. As a waste product, they also tend to become mixed with surface gravels and fine soils, clays, etc. A process for cleaning oily solids must be able to handle coarse as well as fine material.

Tables 3-1 and 3-2 show typical chemical and physical properties of oily solids.

4 QUANTIFICATION OF PRODUCED OILY SOLIDS

Heavy oil operations cover the areas shown in the map (Figure 3-1). The quantities of oily solids produced by operator and area are summarized in Table 3-3. For reference purposes only, Table 3-4 is provided, showing the heavy oil production rate and the corresponding oily solids generation in each major areas.

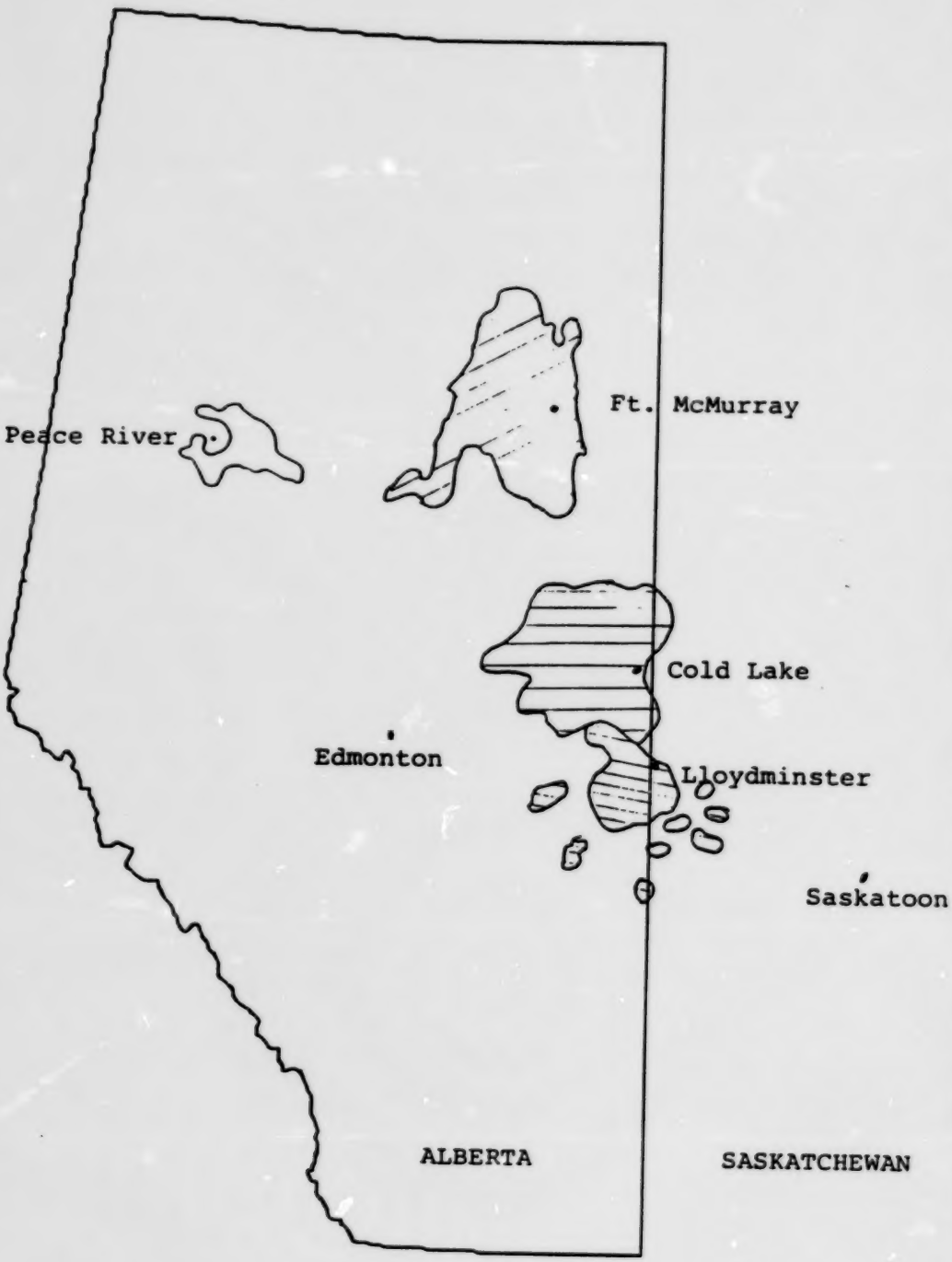


Figure 3-1 LOCATION MAP - HEAVY OIL PRODUCING AREAS

TABLE 3-1

Characterization of Produced Oily Solids
(Typical Chemical Properties)

	Ft. McMurray	Peace River	Cold Lake	Lloydminster SaskAlta Coop
				Oily Sand
Basic Analysis (%)				
Hydrocarbon		22-67	13 (10-20)	12 2
Water		10-34	7 (5-15)	5
Solids		12-50	80	80
Chemical Properties				
Hydrocarbon Phase				
Parafins				
Olefins				
Aromatics				15-17.5
Benzenes & Benzo-Compounds -				33.9
Naphthalenes -				23.3
BTX -		3500-13,900 ppm (of oil)		-
Organic Composition				
Asphaltines	24.0%	12-14%		15-18.4
Neutral Nitrogens				16.5-17
Acids & Bases				0.73-2.2
Resins				13-18
Aliphatics				33.2-38
Aromatics				15-17.5
Inorganic Heavy Metals				
Vanadium	210 ppm	<0.03%		49-146
Nickel	80 ppm	0.02-0.11 ppm		28-94
Iron	500 ppm	2.8-58 ppm		0.6-600
Lead		0.4-1.3 ppm		
Ash % Wt.	0.7			

TABLE 3-1 (CONT'D)

Characterization of Produced Oily Solids
(Typical Chemical Properties)

	Ft. McMurray	Peace River	Cold Lake	Lloydminster SaskAlta Coop		Typical River Water	Drinking Water Maximum Acceptable
				(Apr.87,Stanley) (Leachate)	Produced Water (SRC 88)		
Aqueous Phase							
(Ionic Constituents, mg/l)							
Sodium & Potassium	1400			36-300	620-37,000	30	270
Calcium	40			7.9-140	450-2,700	40	200
Magnesium	30			2.8-15	1.0-7,000	10	150
Chloride	1400			45-500	1430-51,500	30	250
Bicarbonate	1400			3-34	335-1836	150	-
Sulphate	50			0.6-8.9	2.4-26,400	30	500
Total Dissolved Solids	4300			-	-	300	-
Oil & Grease				0.2-1.5	0.01-370	0	0.002
pH	8.2			-	2.6-7.7	7.3	6.5-8.5
Heavy Metals							
Lead				0-0.10	0.05-7		0.05
Nickel				0-0.08	0.1-2		-
Vanadium				0	<0.3		-
Solid Phase (Minerals)							
Quartz	70%						
Kaolinite	12%						
Illite	4%						
Smectite	2%						
Feldspars	2%						

TABLE 3-2

Characterization of Produced Oily Solids
(Typical Physical Properties)

		Ft. McMurray	Peace River	Cold Lake	Lloydminster SaskAlta Coop	Asphalt
Physical Properties						
Hydrocarbon Phase						
Gravity		8.2 API				
Viscosity		8-20,000 GP(100°F)	80-200 GST(70°C)	CP	CST	60 - 200 CP (60°C)
Pour Point		7°C		IBP 80 - 110		175 - 230
Flash Point °C						
Aqueous Phase						
Solid Phase						
Specific Gravity						
Size Distribution		(% passing)		*	(Lindburgh)	
(Gravel)	+6.4 mm	100		50	93	30
(Sand)	28 Mesh	99			75	
	65 Mesh	97			36	
	150 Mesh	90	65-90		?	
(Silt)	200 Mesh	76	50-87		15	
	325 Mesh	15	35-85		?	
(Clay)	-2 MICRON	2	<2		?	
Slurry						

* From well sites, 111 blend of oily sand and gravel used in road surfacing.

Table 3-3

Produced Oily Solids

Inventory and Production Rate

	Inventory m^3	Production m^3/Year
Peace River		
- Shell Canada Resources Ltd.	200	70
Ft. McMurray		
- Husky (formerly Canterra, Lease C-87)	?	?
- Texaco (Lease C-51, Shut Down)		0
Cold Lake		
- Esso Resources Canada Ltd. (Grand Center)	up to 6 000	6 000
- BP Canada Ltd. (Wolf Lake, Shut Down)		0
- Suncor (Ft. Kent, Shut Down)		0
- Petro-Can		
Lloydminster	75 302	75 302 (1985)
	79 722	56 939 (1987)
	69 247	40 650 (1988)

Table 3-4

Heavy Oil Production and
Oily Solids Generation Rates

Major Production Area	Heavy Oil Production m^3/Year (bpd)	Oily Sands Production m^3/Year
Peace River	510 000 (8 800)	70
Ft. McMurray	17 500 (300)	?
Cold Lake	5 220 000 (90 000)	6 000
Lloydminster - 1988	4 431 613 (76 400)	40 650

With respect to solids phase elemental analyses, they are of little significance since such metals are tied up in minerals which are stable.

i.e.	Vanadium	-	Vanadite
	Titanium	-	Rutile & Ilmenite
	Iron	-	Magnetite, pyrite, Marcasite
	Lead	-	Lead sulphide
	Copper	-	Oxides & Carbonates
	Barium	-	Barite (drilling mud)
Na, K, Ca, Mg, Al, Zn, Fe		-	Clay minerals

Under normal conditions they do not leach, nor will they burn. Under high acid or high heat conditions they can be leached or smelted (gasified). Each mineral is different in leaching and gasification characteristics.

Summary of Production Rates

Each area produces a different waste which is characteristic of their own operation. The following describes briefly that information.

Peace River:

Slop oil pit, mostly hydrocarbon, and solids with only 200 m^3 inventory and 70 m^3/yr production. The process required to clean this small quantity should be incorporated into the plant.

Cold Lake:

Oily sand mixed with gravel from well sites in quantities of about 6 000 m^3/yr.

Sask-Alta Waste Disposal Cooperative:

Produce large quantities of oily sand (facilities between 40-75 000 m^3/yr) of highly varied quality and analyses as per the tables. Both oily waste and leachates have been studied extensively, providing all the necessary information for testing.

Ft. McMurray

All the information shown herein is from published papers.

5 CURRENT PRACTICE IN CLEANUP AND DISPOSAL

Current practice of cleanup and disposal of oily solids, while varying with each operation, are oriented to the cheapest and most convenient method possible for disposal within environmental and government guidelines.

At Peace River, Shell Canada Resources impounds their oily solids in a concrete "ecology pit" where free oil and water are skimmed and recycled to the plant. The concentrated solids are periodically removed and impounded in a clay lined (sealed) pit for possible reprocessing or other disposal in the future. Oil contaminated well site aggregates are not comingled with oily produced solids but are stockpiled separately.

At Cold Lake, Esso Resources has "Ecology Pits" made of concrete where the solids are concentrated (settled), water clarified and free oil recycled to the plant. Remaining oil and solids are mixed with gravel and road building material and used locally for secondary road improvement. This practice which is currently allowed by the Alberta Energy Resources Conservation Board (ERCB) as a measure requiring further assessment of its environmental acceptability, and is described in more detail in the technology section of this report. Should the roads eventually be abandoned, the surfaces can be ripped up and recycled by the addition of more asphalt and heat, just as in conventional practice.

At Amoco (formerly Dome), current disposal methods involve mixing the oily sands with gravel and spreading it on country roads in summer and fall. During the remainder of the year the oily wastes are stored in "ecology pits". The oily wastes come largely from the cleaning plant. Well effluent is separated into oil, water and sand in a free water knock-out or treating vessel. Oily sand which accumulates in the vessel bottom is flushed to desand tanks

which are cleaned out with a backhoe. Oily sand is then trucked to ecology pits. Groundwater is monitored from two wells near the pits.

The current practices can be categorized as temporary measures and therefore a long term solution shall be found to eventually dispose of the ever accumulating produced oily solids.

SECTION IV

TECHNOLOGY SCREENING FOR FIELD ASSESSMENT

SECTION IV

TECHNOLOGY SCREENING FOR FIELD ASSESSMENT

This section describes the approach to soliciting information and evaluating technologies which would be suitable for the cleanup of oily solids.

During December of 1989, advertisements were placed in Oil Week, Calgary Herald, and the Toronto Globe & Mail, soliciting interest in submitting technology information for the cleanup of oily solids produced from heavy oil operations. In addition, major known proponents were sent letters requesting their information for the study. The summary of these responses is included herein and the actual responses appear in Appendix E. The technologies were then evaluated and a Kepner-Tregoe analysis performed to select the most potentially promising for this application. Selected proponents were then asked to submit capital and operating costs for 1 m^3/h and 10 m^3/h facilities.

1 IDENTIFICATION OF TECHNOLOGY PROPONENTS

In addition to those proponents identified by advertising, Mr. Gary Lorenz of Husky Oil Operations Ltd. added other known proponents to the list. Appendix A contains the Invitation Package For Submitting Technology Information and Oily Solids Data and Appendix B the Media Advertising Display.

2 SUMMARY OF TECHNOLOGY INFORMATION SUBMITTED

Companies responded with technology packages of various kinds of processes. Those technologies are categorized and summarized in the following sub-sections:

2.1 Thermal Processes

2.2 Fixation Technologies

2.3 Hot Water Extraction

2.4 Solvent Extraction

2.5 Chemical Processes

2.6 Other Processes

2.1 THERMAL PROCESSES

Thermal processes operate at an elevated temperature, 450 - 1 200°C approximately. Pyrolysis (partial and fully pyrolytical), combustion, incineration and other variations exist. All thermal process plants require gas cleanup, particulate removal and ash handling subsystems. Depending on temperature levels and metals in the feed oily solids, metals and mobile ions in the combusted solid may have to be subject to leachate tests prior to final disposal.

2.1.1 AOSTRA Taciuk Processor (ATP)

AOSTRA Taciuk Processor (ATP) recovers the oil content of oily waste sludge and has been tested at 4.5 t/h. The UMATAC processor consists of a multi-chambered rotary kiln followed by a simple cooling/condensing process and a fractionator. Coke produced from thermal cracking of asphaltenes is recycled as fuel for the process which operates at 450 - 600°C. Stack gases are cycloned, filtered through a bag house, and wet scrubbed. The hydrocarbon product consists of a light oil (partially cracked). The solids containing "high concentrations of several metals and mobile ions" can be disposed of by secure landfill. The off gases are generally flared or can be recycled to the combustion zone for further destruction, resulting in very low ground level concentration of SO_2, H_2S and/or NO_x. The flue gases generally carry over sand and clay dust from the processor and must be cleaned to meet emission standards (0,092 g/m^3). Aqueous streams are blended with the wet scrubber discharges resulting in low BOD and COD values. In most

cases, however, effluent water must be subject to secondary treatment for phenol removal and for oxygenation to enable re-use or land disposal.

The UMATAC processor will process all types of oily solids including hay bales and spent filters (if they are shredded). The product is partially upgraded and will therefore command a higher price.

Tests have been run on 380 tonnes of oily waste from Mobil Kitscoty and Celtic, Esso Cold Lake and BP Wolf Lake. The product streams showed improvement over existing methods. Most of the oil was recovered as light oil, and "the process provided an environmentally acceptable disposal option", as remarked by Environment Canada.

The cost of a 10 TPH facility is reported as follows:

Capital Cost:	
Site	$ 95 K
Plant (Supply and Erect)	4 700 K
Water and Utilities	150 K
Waste and Product Handling	900 K
Other	266 K
Capital Cost Total	$ 6 000 K
(Submitted data indicates $5 million excluding Royalty, Engineering Licencing Fees and Engineering Services Fees)	
Annual Operating Cost:	
Labour	$ 965 K
Equipment	408 K
Maintenance and Supplies	1 038 K
Indirects and Royalties	509 K
TOTAL OPERATING COST	$ 3 000 K
Annual Operating Hours	5 000
Annual m^3 (50,000/1.3)	38 460
Capital Cost (3 yr. straight line)	$52/$m^3$

Operating Cost	$78/m^3
Haulage (10 km) @ $0.08/m^3.km	$0.80/m^3
Credit for Oil	($5.30)
TOTAL COST OF PROCESSING	$125.50/m^3

The cost is calculated to be $125.50/m^3 until payout (3 years, no interest charges) then $73.50/m^3 thereafter. Overall, UMATAC is very willing and capable to commercialize the process. The cost of a 1 m^3/h facility has not been calculated, but would be much higher on a per m^3 basis.

2.1.2 Fluid Bed Combustor

A Fluid Bed Combustor submitted by Pacific Environment Systems Inc., Energy Products of Idaho Inc. (EPI) and JWP Inc. has been tested and proven successful as a process for burning oily solids. Oily solids are fed from a hopper up a transfer conveyor into a retort type fluid bed combustor where the hydrocarbon is burned at about 1 038°C. Fly ash is cycloned to remove dust, and the combustion products discharged to atmosphere. Tests on clay soaked with oil showed 1.7% carbon carryover in the product. Carryover for oily sand would undoubtedly be less. The stack gas yielded low NC_x, CO and hydrocarbon emission at a low excess air rate. SO_2 emissions can be controlled with limestone addition. Air particulate emissions are less than 0,092 g/m^3. A process sketch is shown as Figure 4-1.

The advantages of this process are portability of the core unit, (small size compared to the Taciuk processor), simplicity, flexibility and reliability of the processor, and the financial strength of the partners who currently operate 65 waste plants worldwide and are proposing the Trochu, Alberta tire burning plant.

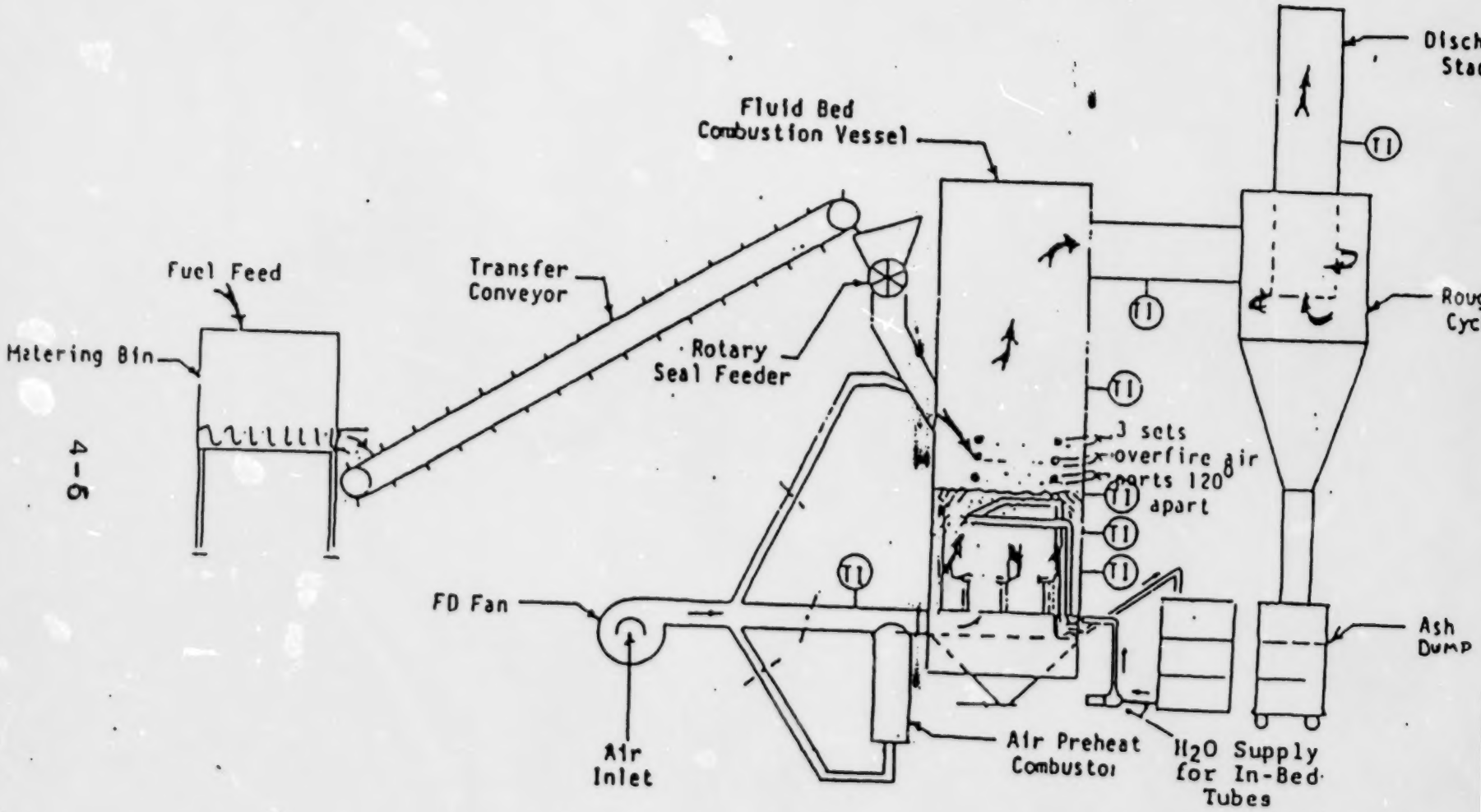


FIGURE 4-1 EPI Pilot Plant Test Facilities
Schematic Diagram

They prefer to own the plant themselves and would be prepared to operate it at 10 m^3/h (56 000 - 60 000 m^3/yr) for \$33-\$35/m^3. Water and natural gas are required for startup only, but electricity cost is excluded. Electric power will be less than \$1.50/m^3, and similarly the costs of other utilities will not be significant.

The process appears to be very cost effective and the owners are enthusiastic about working with the CPA. A demonstration plant burning wood chips is currently operating in Idaho. JWP revenues are approaching \$2.0 billion per year and they are widely known experts in waste treatment and fluidized bed/burner technology.

2.1.3 Anachemia Pyrolytical Process

Anachemia Solvents Limited have a licenseable process which blends the oily sands and oily sludge along with a solvent, recovers the solvent and burns the gas pyrolytically. The process would likely be mechanically complex since the main units are a blender-flasher, reactor and cyclones, solvent recovery unit, after burner and baghouse; and would therefore not likely be economical at 10 m^3/h and 1 m^3/h (no costs were submitted). The process uses new technology not in common use (spouted bed pyrolytic reactor). Residual heat from the process would have to be utilized in the existing heavy oil plants or dumped.

Figure 4-2 shows a schematic process arrangement.

2.1.4 Dolen Burner

The Dolen Burner supplied by the Environment Protection Company (EPC) is a mobile burner specifically designed to eliminate hydrocarbon in sand, gravel, clay, soil, sludges, etc. The burner can reduce oil content to less than 0.8% at capacities up to 20 TPH.

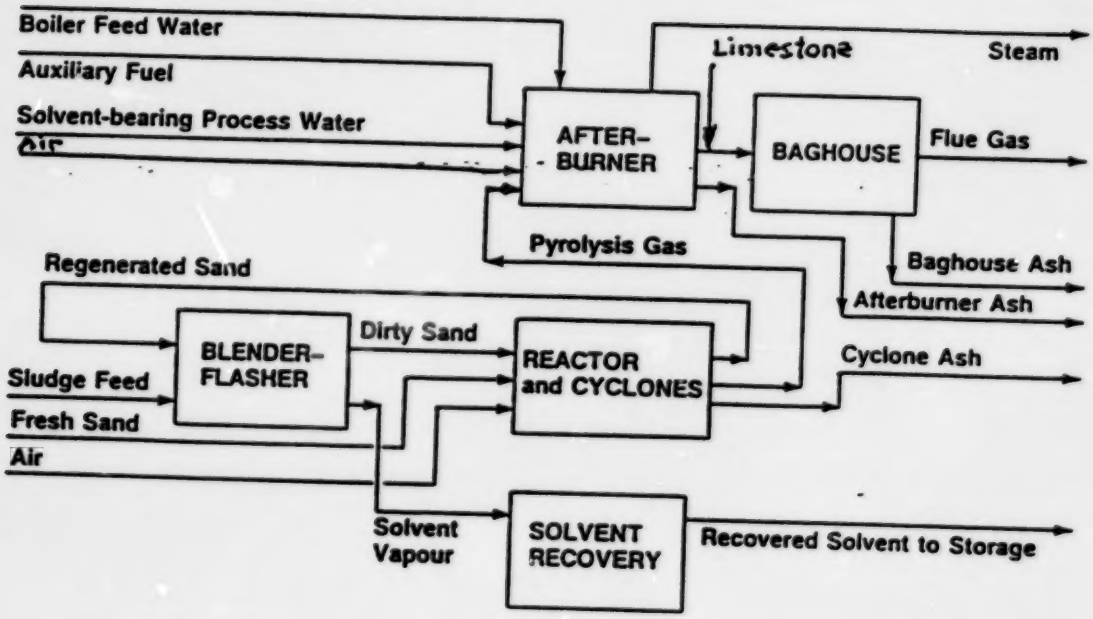


FIGURE 4-2 Anachemia Pyrolytical Process Flow Diagram

The burner was financed by Canadian Oil Reclamation Ltd. (COR Ltd.) who is the major share holder of EPC. The burner is completely mobile and can be dismantled and reassembled in less than a day.

Oily solids, fed into a hopper with a front end loader, are conveyed to the burner. The combustion product solids are conveyed to a truck for final disposal. The burner itself consists of a propane burner, a rotating drum, a filtered baghouse, an afterburner and stack. Chlorides, sulphates and other metals/minerals are concentrated in the solids.

Costs are said to range between $50 and $100/t ($65 to $130/m^3) excluding transport of the solids and landfill. Highly saline product solids would result in chlorides leaching out of the landfills.

2.1.5 Lurgi-Ruhrgas Process

The Lurgi-Ruhrgas Process has been commercially proven for cracking naphtha, crude oil and coal and has been used in Germany since the late fifties. It is a direct retorting process involving a circulation/reaction chamber operating at 675°C. The flashed hydrocarbon vapours are dedusted, fractionated and condensed. The retorted sands pass into a surge hopper where cracking is completed. A sand cooling section is then used to preheat air and produce steam. The spent sand contains coke which is combusted in the first stage of the fluidized bed. The products are light oil, naphtha and sour water.

A process schematic diagram is shown as Figure 4-3.

Typically, an 11.5% bitumen sand would result in 85% recovery of hydrocarbon and the sands would be hyrocarbon free. Potentially, any salts would be volatilized and condensed into the

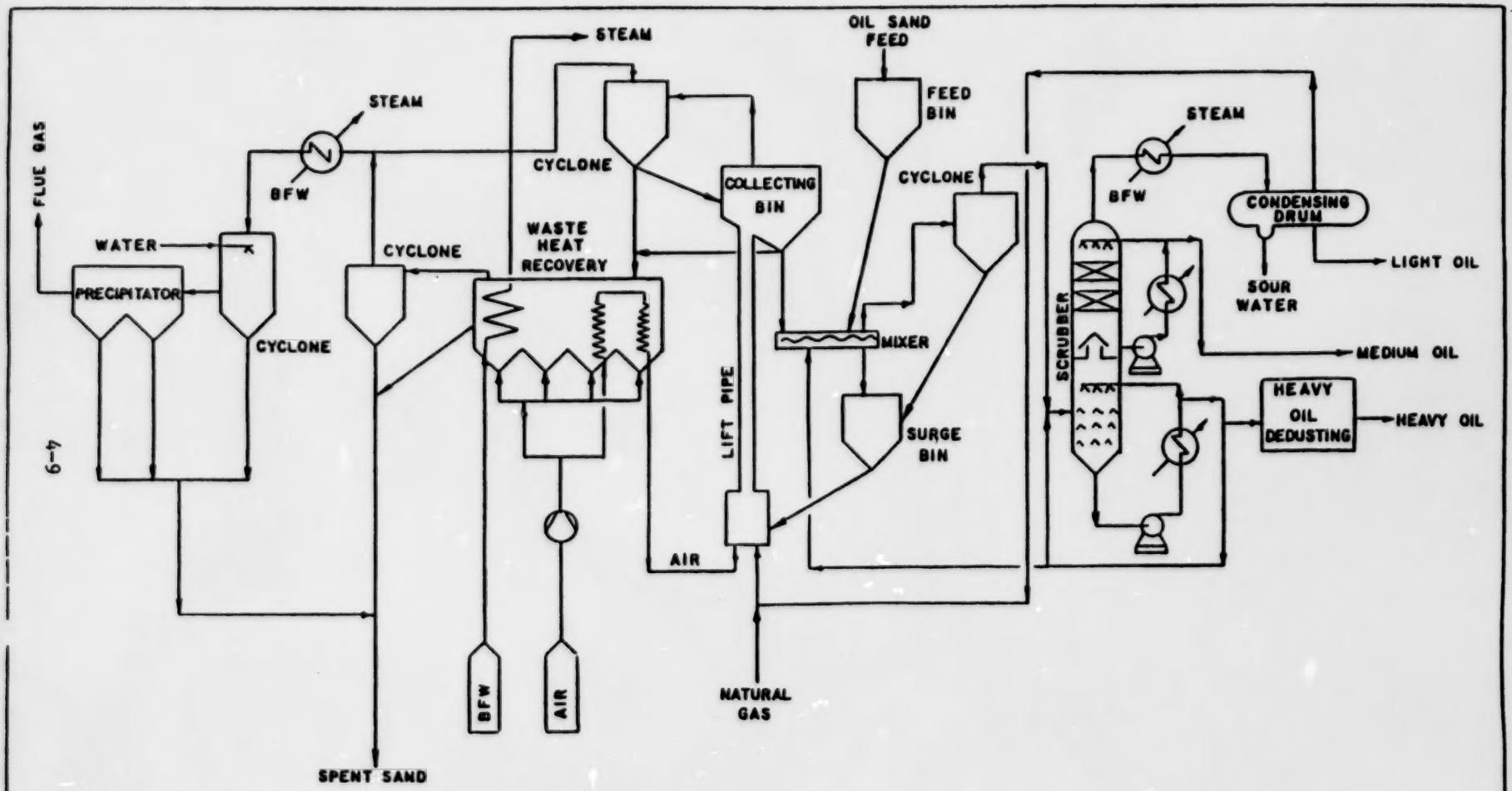


FIGURE 4-3 Lurgi Process Flow Diagram

water and oil phases. The complexity of the process would not make it as portable as Taciuk so the overall costs would likely be higher.

2.1.6 Superburn Incinerator

The Superburn Revolving Fluidized Bed Incinerator designed by Canadian Waste Management as shown in Figure 4-4 starts by heating a fluidized sand bed to 600-700°C with a fuel, either oil or gas. Wastes are fed into the incinerator, come into contact with the hot sand and are heated to the point that they are reduced to gaseous vapour and a small amount of ash (usually less than 1% of original amount). Low concentrations of nitrous oxides result because of the excellent temperature control and any residual acids created can be neutralized with dolomite or limestone. The Superburn incinerator claims to improve combustion efficiency by providing cross and vertical mixing of the combustion gases in a three compartment rectangular furnace. The gases and solids are controlled so as to induce a cyclone effect. The process is widely used in Europe and Japan.

The claimed advantages of the process are the following: Very small quantities of residual ash remain after firing (<1%). Low maintenance costs result since there are very few moving parts within the incinerator. Size varies from a mobile unit capable of handling 14.4 tpd, to a fixed unit that is able to handle 500 tpd.

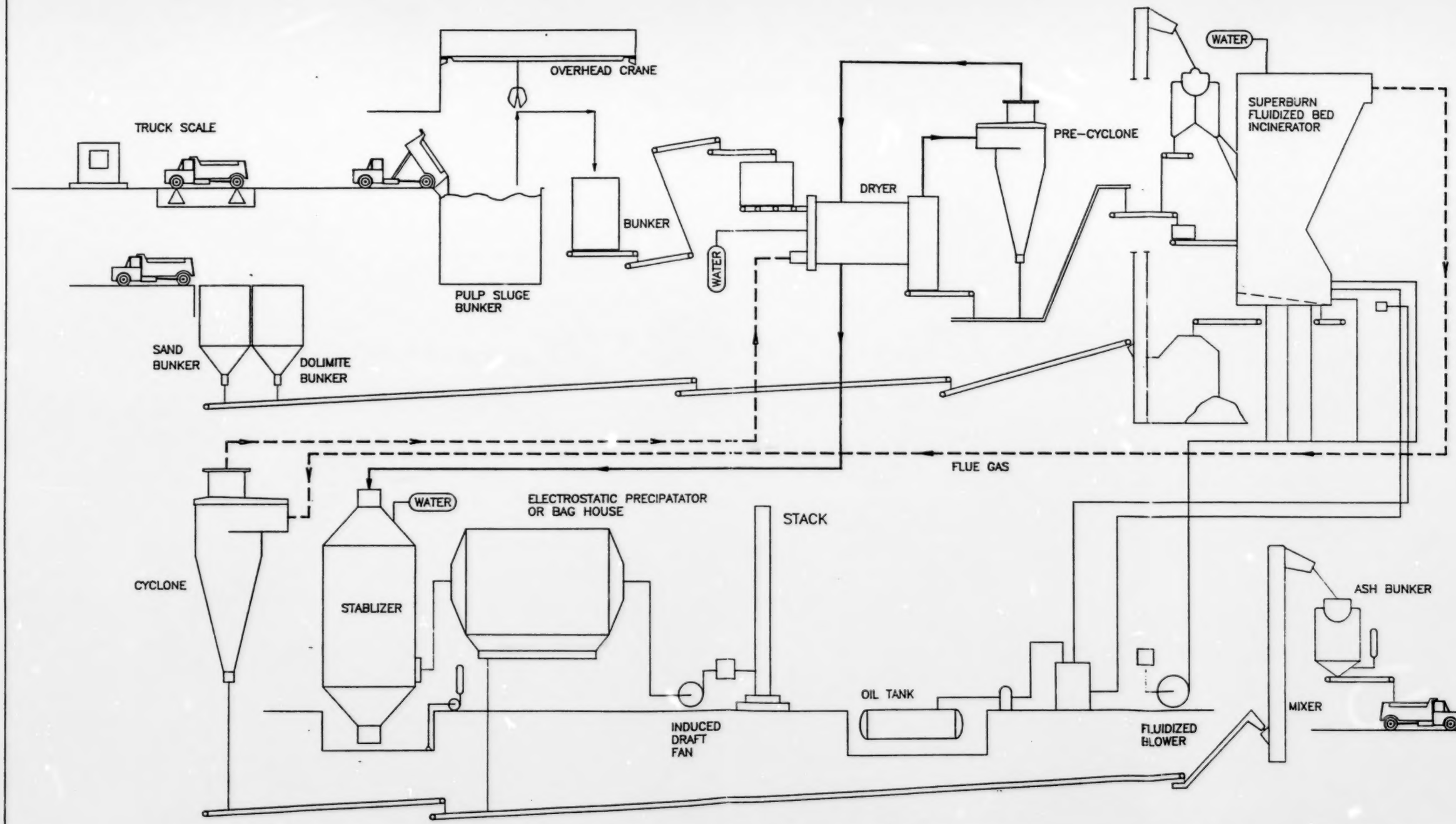
Disadvantages of this system are the following: The requirements of oil or natural gas as a fuel, as well as use of dolomite or limestone to neutralize the stack gas acids created. The process utilizes noise suppression equipment which seem to indicate that the equipment may be hard to work near.

SUPERBURN SYSTEMS LTD.
201-2034 W 12th STREET
VANCOUVER, B.C. V6J 2G2

PH: (604) 732-1077

Figure 4-4 Superburn Fluidized Bed Incinerator

FLOW DIAGRAM



Utility requirements include electrical power for the air fans, water for quenching the exhaust gases, coal or natural gas, and limestone or dolomite.

Operating Basis

o	Operating hours:	not stated
o	Utility rates:	Alberta Market Rates
o	Operating labour rate:	$12-$20/h
o	Capitalization:	25 years on 10% interest rate
o	Size of unit:	10 tpd

Operating Costs (10 TPH units)

o	Based upon capacity and waste stream characteristics	$130-$250/t

Capital Installation Cost (10 TPH unit)

o	Based upon costs of installation excluding royalty, engineering license fee and engineering service fees	$3.8 million

2.2 FIXATION TECHNOLOGIES

The technologies which do not subject the oily solids to physical or chemical separation processes and thermal treatment are categorized as fixation methods. The fixation methods are unique in that the source oily solids are transferred, physically, as an ensemble from the production site to other environmentally safe location. The oily solids may also be physically "fixed" or "contained" in such a manner that they become "permanently" isolated from the environments.

2.2.1 Road Surfacing

Esso Resources Canada Ltd. has developed a Road Surfacing Technique which has been accepted by the Energy Resources Conservation Board for the "Application of Oily Sand".[1] The road surfacing methods use commonly available road building equipment such as graders, wobbly wheel packers, sheep's foot packers, rotovators, and a self propelled mixer; to "achieve a road surface which approaches asphalt in appearance and performance". Typical, oil sand containing 13% bitumen, 7% water, and 80% solids is mixed with gravel, on about 1:1 basis, in a sand pit with a front end loader. Parallel windrows are prepared on the road to be surfaced with graders such that a trench is formed. Sand pit material is then dumped between the windrows. Bitumen is also applied with a spreader bar depending on the specifics of the road bed. The windrows and sand pit mine are then combined, mixed and spread by a grader. The packers then work the surface to close to 100% compaction. Several lifts are applied in this manner. The resulting road surface will accommodate 35 tonne axle loads in all weather conditions. Road surfacing should be done in hot, dry weather.

"Oily sand road surfacing costs average $10 000/km, ecology pit cleanout average $2.50/$m^3$, not including the cost of gravel addition. Including sand pit handling costs, oily sand byproduct usage costs about $70/$m^3$."

Road surfaces can be ripped and reclaimed. However, these costs are not accounted for.

This process is dependant on continued government approval of road surfacing as a disposal technique as well as the

---

1. ERCB believes that alternative technologies shall be pursued, while accepting the road surfacing application.

availability of gravel in the area. In Fort McMurray, gravel would command a premium price.

Sask-Alta Waste Disposal Cooperative has also developed a procedure for "Waste Disposal on Roads", primarily as "a dust suppressant or for road surfacing". "Wastes are applied to the roads in accordance with guidelines that have been developed by SAWDC in consultation with the regulatory agencies of each province". A limiting factor is that the oily waste fluids must not contain free salt water or hazardous chemicals. Oil is applied at a rate of 12 m^3/km of road, not to exceed 40 m^3/km and is weather dependant.

Groundwater studies concluded that heavy oil wastes on municipal roads "will generally not lead to contamination of groundwater. Most of the wastes can be considered as mildly toxic, but if certain precautions are taken the concentrations of toxic constituents derived from the wastes could thus be considered of economic value for road surfacing". "The clays and carbonates in the roadbeds should be sufficient to maintain neutral pH and to immobilize the trace metals contained in the wastes".

Although road surfacing is claimed to approach asphalt paving, SAWDC studies show that leaching of some hydrocarbons does take place. Asphalt is a non-volatile, poly-cyclic structured hydrocarbon with a high carbon to hydrogen ratio. It is produced as treater or cracker bottoms and is solid at normal atmospheric temperatures. It is sticky at 37.8°C but is stable and does not migrate, whereas, bitumen contains light ends and does migrate. Penetration tests of bitumen substituted asphalts do not approach those of conventional asphalts. Fine sand and clays render the pavement more easily subjected to "pot holing" and the surface is somewhat more slippery when wet.

2.2.2 Fujibeton Solidification Technology

The Fujibeton Pollution Control Solidification Technology designed by Canadian Waste Management Inc. mixes toxic wastes, proprietary inorganic polymers and Portland cement. The result is a concrete that can be used in construction. Oily sand would be fed to cement mixer, mixed with chemicals (inorganic) and Portland cement and poured into a construction project.

The claimed advantages include the relative use of technology that is currently available. There is little heat generated by the mixing, and thus small loss of gaseous vapours. The process has been effective in treating and stabilizing organic and inorganic contaminants. The process has been widely used in Japan.

Disadvantages of such a process include questions of storage of the oily sand prior to mixing. The elements would have to be held while a buyer could be found since the cement compound will harden immediately after mixing. Environmental risk would have to be considered since the concrete may not last forever. The concrete may erode, releasing the original oily wastes. Consequently, distribution of these materials may have been widespread, resulting in a potential hazard which may also be widespread.

Utility requirement are use of a cement mixer, water and the Fujibeton mixture.

Operating Basis

- Utility rates: Alberta Market Rates
- Operating labour rate: $12-$20/h
- Capitalization: 25 years on 10% interest rate

Operating Costs

- Based upon capacity characteristics, this process costs are expected to vary with site and waste quantities.

- Estimated costs of disposal are about $150/t or $300/m^3.

2.2.3 Voest-Alpine Montage Solidification Process

The Voest-Alpine Montage (VAM) Solidification Process proposed by Canadian Waste Management Inc. treats wastes with calcium oxide and water to produce calcium hydroxide and a fine water repellant powder that is compacted to make a product that can be used in roads. The reaction is exothermic. The unit, placed on a flatbed truck, contains a homogenizer and auxiliary equipment for adding reactants and additives.

A claimed advantage of such a system is relative simplicity. Trucks will be needed to haul the wastes to and from the disposal site. No special handling equipment is required because the resulting product is classified as non-hazardous. Ordinary construction equipment is required for excavation of soils and a hydraulic pump for moving the sludge. Air emissions are controlled by the addition of cyclones, gas scrubbers, etc.

A disadvantage of this process is that air emissions are checked only with the inclusion of additional equipment. This cost was not included.

Utility requirements include an electric generator, water, additional equipment to control air emissions.

Flow Diagram of VAM is attached as Figure 4-5.

Operating Costs (20 TPH) unit:

- Based upon capacity and waste stream characteristics, the VAM process can clean up contaminated sites for about $175-$250/t.

Capital Installation cost (20 TPH unit):

- Based upon costs of installation excluding Royalty, Engineering Licence Fee and Engineering Service Fees. $2.8 million

2.2.4 Re-Injection

Re-injection of oily solids has been proposed by Halliburton Services Limited. The injection of sand slurries into rock formations has been practiced in the oil industry for nearly 40 years. It requires that an existing depleted well be converted into a disposal well. Hydraulic fracturing will take up to 75% solids slurries in 250 m^3 batches (less than 10 mesh top size) and inject them at 14 MPa. Halliburton quoted rate would be $75 to $100/$m^3$. This process is proven, competitive and provides a very clean "Cradle to grave" solution to permanent disposal. Halliburton enthusiastically await participation in a demonstration on commercial application.

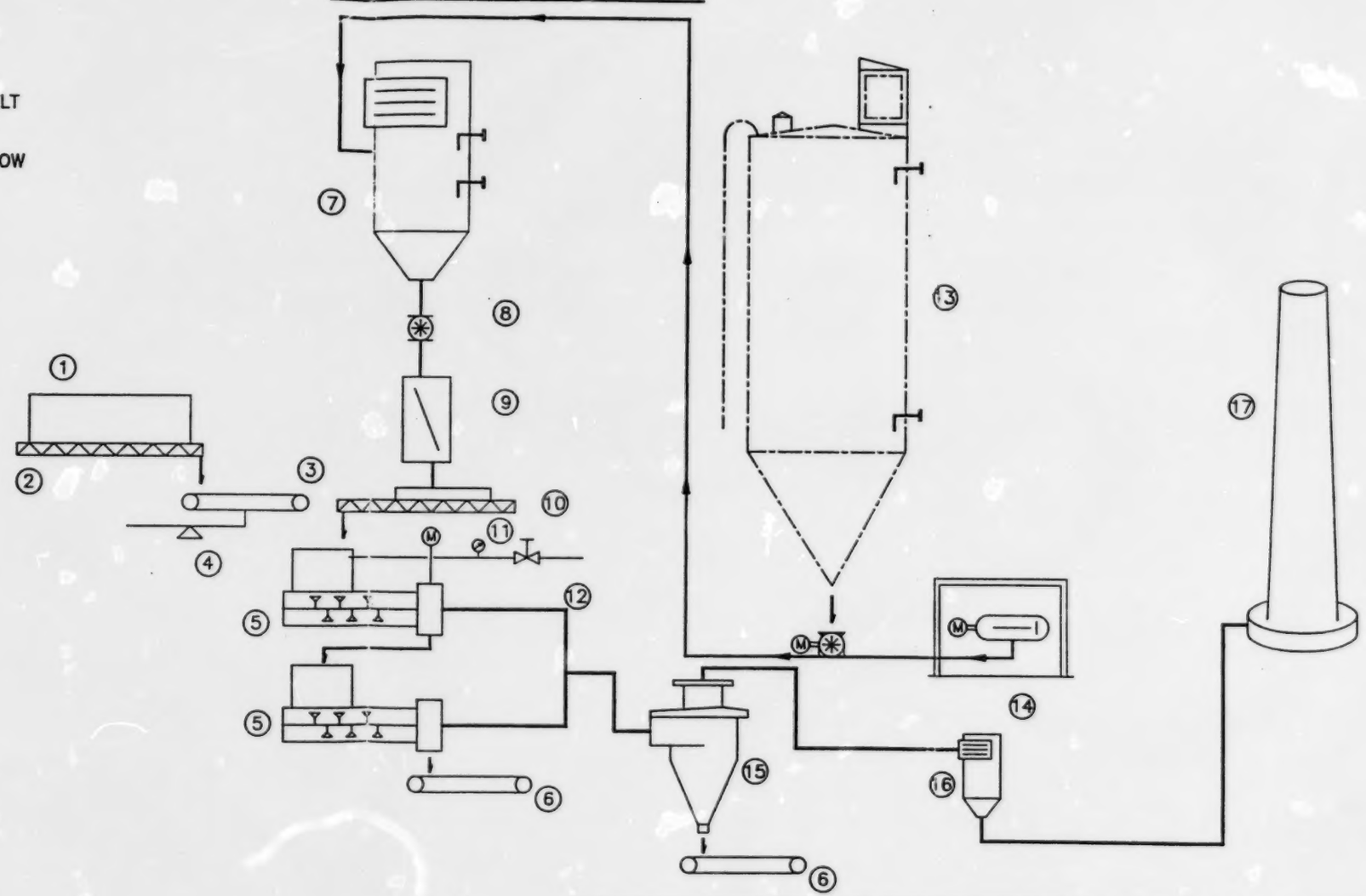
2.2.5 Salt Cavern Disposal

Salt Cavern Disposal is a known technology proposed by New Alta Environmental Services Corporation Salt domes in the Prairie Evaporites would be drilled into, solution mined (similar to Sylrite Canada) and backfilled with oily solids. The salt water would either be reinjected into a different formation or evaporated and used for road sanding and salting during the winter. Current road

Figure 4-5

1 FEED HOPPER
2 PROPORTIONING SCREW
3 CONVEYOR BELT
4 CONVEYOR BELT–BALANCE
5 HOMOGENIZING UNITS
6 FINAL PRODUCT CONVEYOR BELT
7 ADDITIVE SILO
8 ROTARY VALVE
9 MEASUREMENT OF ADDITIVE FLOW
10 PROPORTIONING SCREW
11 FLOW METER
12 WATER INLET
13 STORAGE BIN
14 BLOWING STATION
15 CYCLONE
16 SCRUBER
17 STACK

FLOW DIAGRAM OF A TWO–STAGE PLANT



Canadian Waste Management

505 – 5055 Macleod Blvd. NE
Calgary, Alberta
T2E 6L3

Phone (403)291–5055
Fax (403)291–5054

Date	Drawn by	Checked by	Revision	Rev.

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Title: Flow Diagram Of VAM

Client:

salt consists of 97% sodium chloride and a minimum of potassium chloride. It is supplied by the potash producers of Saskatchewan at little above the cost of transportation. The only disadvantage of salt cavern reinjection is that transport distances of some of the oily solids will be great. The hydraulic backfill will be high pressure and the salt water or salt must be disposed of. The process is not mobile. The greatest advantage of the process is that it is a "Cradle-to-grave" solution. The costs of such a facility would have to be worked out later.

2.2.6 Mobil Sand Injection

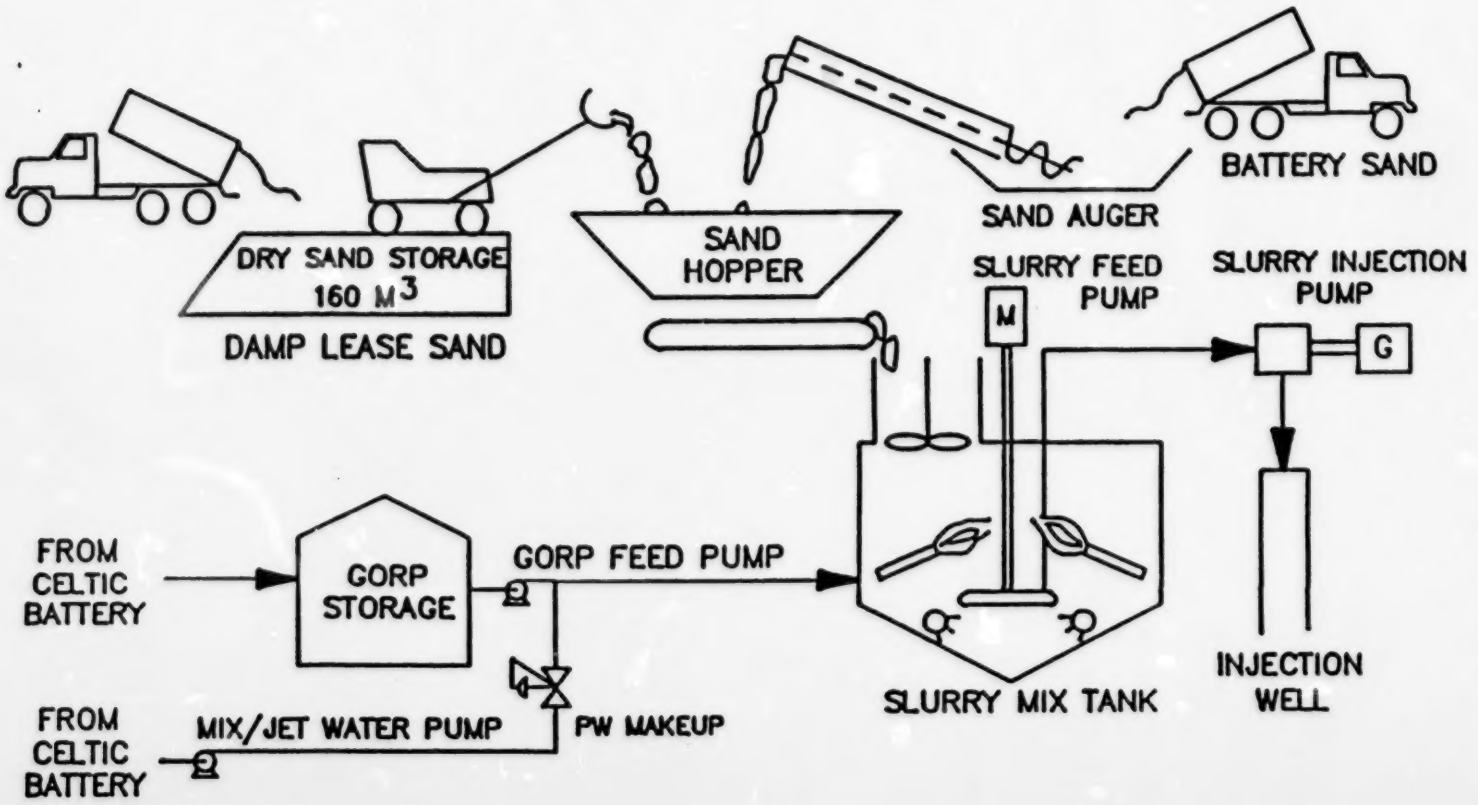
Mobil Sand Injection Process offers a similar final solution to oily solids disposal. In 1989 Mobil hydraulic fracturing 4 000 m^3 of sand and 14 000 m^3 of fluid into a single well at Celtic. The process is confidential, however, Mobil is willing to discuss the technology with those people who are willing to sign a confidentiality agreement. The capital cost of the test facility would be $1.55 million. The operating cost is $20/$m^3$ for handling and $16/$m^3$ injection.

Figure 4-6 illustrates the process using Celtic application as an example.

2.3 HOT WATER EXTRACTION

There are numerous hot water extraction processes (all largely the same) all of which are covered by uncontested patents. All of the processes are basically the K.A. Clark process and are similar to Suncor or Syncrude, with the exception of a middlings stream which is withdrawn from the separation vessel. The processes basically employ a conditioning step (digesting, coalescing, mixing, agitation) followed by various froth flotation machines or API

FIGURE : 4-6
CELTIC SAND INJECTION FACILITIES
PROCESS FLOW SCHEMATIC



separators most of which are commercially available. Some variation exists as to how the gas is introduced to the slurry.

2.3.1 Oily Sludge Extraction Processes

Trans. Couillard, Rouleau at University of Quebec and Ecole Polytechnique developed a process for removal of heavy oil from bottom tank petroleum sludges. The process consists of four main steps:

1. Screening and Mixing (6.5 mm)
   Addition of 1% Na_2SiO_3.

2. First Stage Digestion
   A Wemco flotation machine is used with hot water (90°C) fed down the hollow shaft (20 minute retention time).

3. First Stage Flotation
   Another Wemco flotation machine is used to float off oil. 15°C tap water is added at this stage.

4. Second Stage Flotation
   The remaining solids are digested and floated again in another Wemco flotation machine.

5. Froth Settling and Recycle
   The produced froth is clarified in a thickener and the tailings discharged.

Bench scale testing has shown 99% recovery of hydrocarbons in the case of oil contaminated sands, and 82% recovery in the case of petroleum tank bottoms with two stages of flotation.

The process is likely cost effective on oily solids and can likely be improved upon for tank bottom sludge processing. The process is included in a publication in the AOSTRA library and is not patented. The information is in the public domain. The advantages of the process are that additional stages can be easily added for more severe applications. The disadvantages are that coarse material (+25 mesh) will likely be difficult to pass through the flotation machines, therefore, the process must be preceded by a screening device. The process, although not pilot tested, has demonstrated the difficulty of processing more severe emulsions and oil wet solids.

Cold Lake Oily Sludge Processor developed by Esso Resources Canada Ltd. applies the same K. A. Clark technology as is used at Syncrude and Suncor, but on a much smaller scale.

Esso declined to submit information on the process due to pending patents so a description is not available at this time.

The process has been pilot tested in 1988 and found to be very effective for cleanup of all "ecology pit wastes" including oily sand, gravel from well sites, slop oils and tank bottoms. A 12.5 m^3/h unit has completed conceptual design, process design and general arrangement drawings have been approved. Operating in conjunction with a central processing plant, it is likely to be cost effective (more so than road surfacing). As a satellite plant (stand alone), it must process larger quantities of oily solids so that it can be effectively utilized. The plant and process would be modular in design and totally portable. The process is simple, reliable, and effective. Its only drawback may be that difficult to process (oil wet solids) tank bottoms and slop oils may require greater conditioning times as was indicated in the Trans, Couillard, Rouleau test work.

2.3.2 Clark Hot Water Extraction Process

The K.A. Clark Hot Water Extraction Process, practiced by Syncrude and Suncor, consists of conditioning followed by API separation (clarification) and oily froth cleanup in centrifuges. The clay middlings containing residual oil are cleaned using a variety of froth flotation machines. Recoveries in tarsand are about 90% and would likely be higher in oily solids applications. Tailing solids would contain less than 1.0% hydrocarbon by weight. Current practice is to impound the tailings in a pond and recycle the water.

Figure 4-7 shows the processing scheme.

2.3.3 Kruyer Process

The Kruyer Process developed by Jan Kruyer employs the hot water extraction conditioning process followed by an oleophilic sieve which collects bitumen. Bitumen would be stripped from the sieve using steam and recycled to the existing plant. A Kruyer Process Flow Diagram is attached as Figure 4-8. The process relies on the fact that bitumen sticks to metals. The bench scale tests indicate less than 1% solids in the bitumen and 90% recovery of the hydrocarbon (i.e. about 1 to 1.5% hydrocarbon on the solids which must be landfilled). Oily solids produced from wells would likely result in higher yields. The process still requires demonstration plant testing. Economics are deemed to be comparable with hot water extraction. Kruyer failed to respond to invitation.

2.3.4 Suncor Oily Sludge Cleanup Process

The Suncor Process consists of a tumbler for conditioning with hot water, steam, caustic (if required) and if need be, grinding balls which will break up aged or viscous tank bottoms,

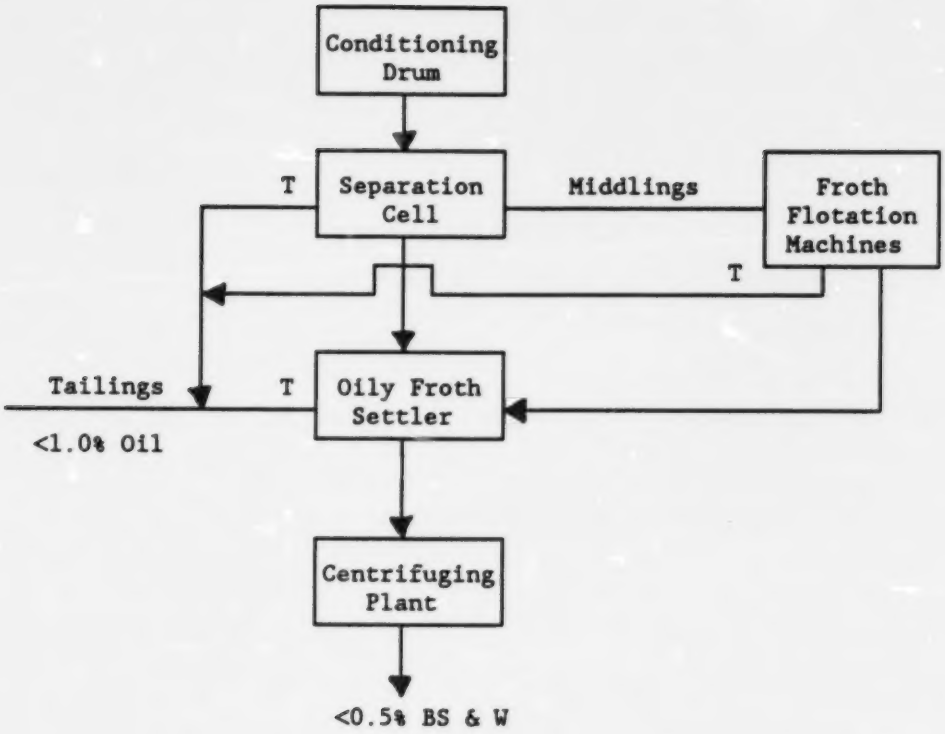


FIGURE 4-7 Clark Hot Water Process

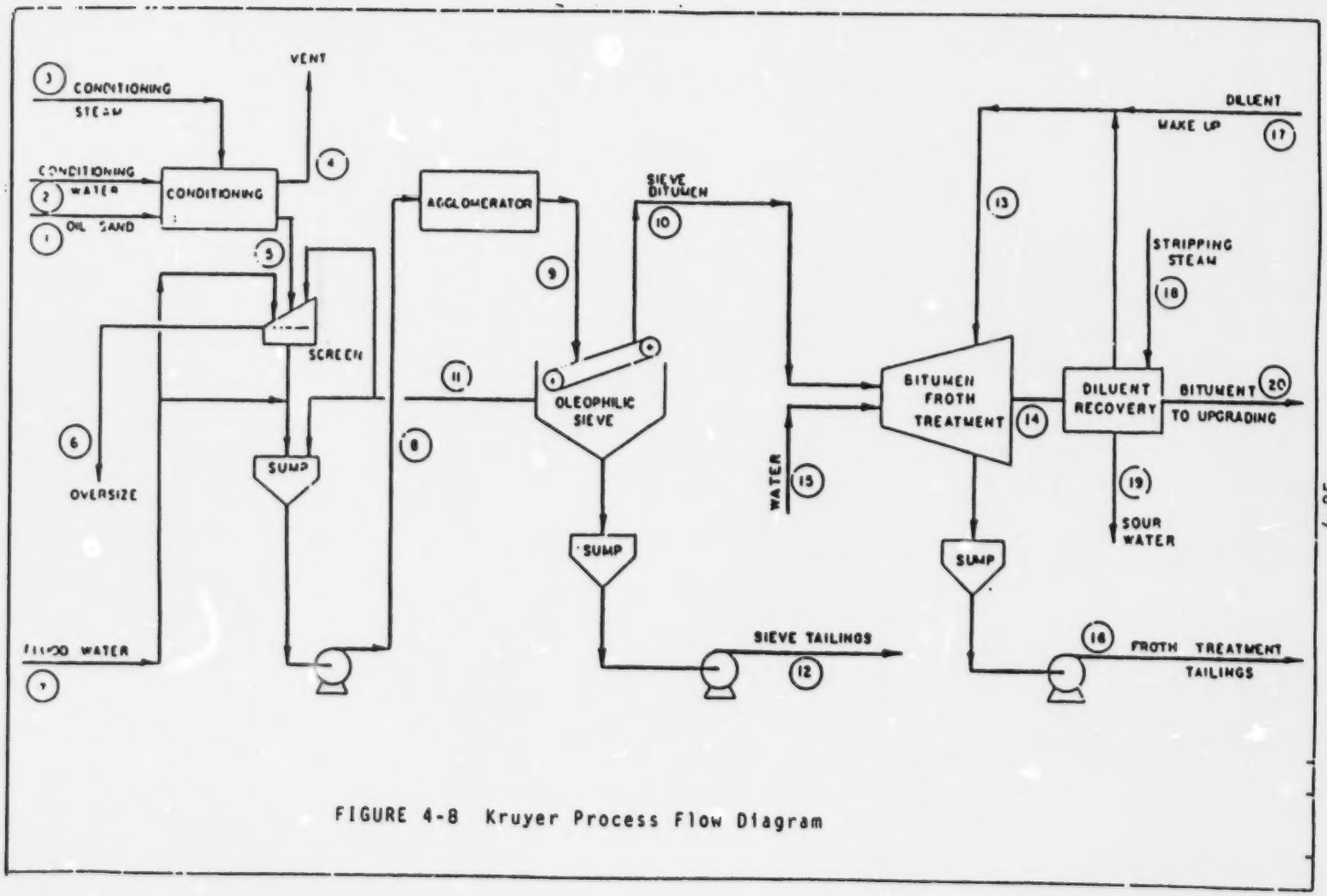


FIGURE 4-8 Kruyer Process Flow Diagram

4-25

slop oil, etc. The conditioned sludge is then pumped to two stages of conventional froth flotation machines which produce a hydrocarbon froth and sludge tailings. Tailings can be dewatered by screen bowl centrifuge or other means as required by the circumstances.

This process has been tested extensively on the bitumen rich sludges in the bottom of pond #1. The process would require a front end loader and one operator, so it would be very competitive with any other hot water extraction process. Suncor's experience in this regard is extensive and would be an asset during further development in the future. Costs would be developed if the CPA are interested in proceeding further.

2.3.5 STS Process

ASTCO, STS Process by Alberta Solids Treatment Company Ltd. is another conventional hot water extraction process employing agitation, coalescing and API separation. Oily solids and crude oil emulsions are dumped directly into the first of three compartments where primary heating and mixing allow "free water and free solids to separate immediately." The first chamber mixes the feed and hot water using a pump, prepares the oily drops through coalescence and scrubs any oil wet solids. Emulsions separate and rise through a heated water barrier in the secondary high turbulence cleaning compartment. Finally, the slurry moves into the third quiescent chamber where the solids settle, oil rises to the surface and water is removed from the centre of the chamber. Sample tubes are used to control the position of the interface. Settled solids are advanced along the bottom trough of the chambers with an auger and are discharged with a scraper drag conveyor or bucket elevators. The solids are only partly dewatered. "Continual selective flow control" allows the separation of tighter emulsions that require

longer retention times than lighter emulsions which advance quickly through the chambers. "Mechanical breakers and coalescing baffles inserted in the flow path remove solids and water from the emulsion yielding production quality oil." The retention time through the three compartments is about 4 hours.

The production model has been used to test AMOCO oily solids at Lloydminster and is currently in use at Taber, Alberta cleaning 80 m^3/d. Residual solids and oily sludge containing clays are being successfully blended into non-productive top soils to help reduce perspiration and trap water. The oily sludge also acts as a fertilizer. Test data on products indicate less than 0.5% solids in the oil product stream. The sand tailing was 0.51% hydrocarbon and 34 ppm chloride. Water is recycled to the process or reinjected into the wells. Chemical consumption for processing slop oils is 5-8 000 ppm at $4.40/L. Oily sand treatment should take less chemical (could be as low as zero).

Operating costs for a 10 m^3/hr unit are judged to be as follows:

Natural Gas @ $\$78.09/10^3m^3$	$\$1.50/m^3$
Electric Power	$\$0.78/m^3$
Chemical	$<\$30.00/m^3$
Labour 2 people @ $30.00/h	$\$6.00/m^3$
Maintenance and Parts	$<\$5.00/m^3$
Other	$\$5.00/m^3$
TOTAL OPERATING COST	$<\$50.00/m^3$

Guessing that the capital cost would be about $1 000 000 for process equipment and $500 000 for ancillaries and a front end loader, a 3 year straight line payback without interest would add $\$11.90/m^3$ to the cost. Overall this process would certainly be competitive with road surfacing at $70 m^3/h.

The STS Process might be improved by adding air to the final chamber or the second chamber. Although the Company is small, it is willing to commercialize the process and has been in the oily sludge cleanup business.

ASTCO's very rough response to a 5 m^3/h facility reported costs as follows:

Natural Gas	$1.50/m^3$
Electric Power	$0.75/m^3$
Chemical	0
Labour 2 people @ $30/h	$12.00/m^3$
Maintenance and Supplies	(not calculated)
Other	(not calculated)
TOTAL OPERATING COST	$14.28/m^3$

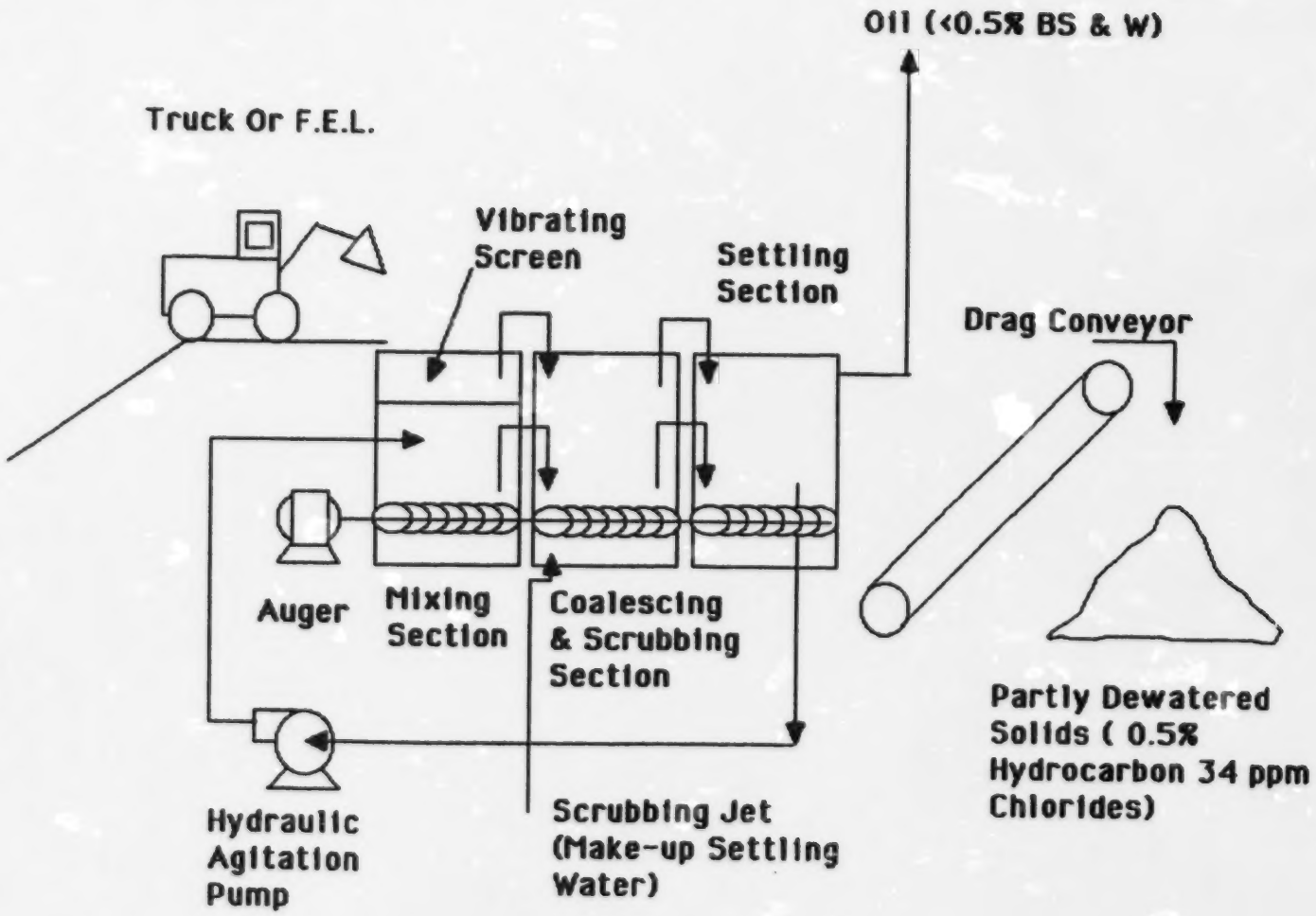
This cost assumes no chemicals will be required and a front end loader operator can work as a plant operator. The capital cost of this facility was about $600 000 which is about $8.00/m^3$.

An ASTCO STS Process schematic is shown as Figure 4-9.

2.4 SOLVENT EXTRACTION PROCESSES

Solvent extraction processes utilize diluent or solvent to remove greasy oil from solids, reduce the specific gravity of the hydrocarbon and separate the hydrocarbon from the liquor by gravity (API separators or centrifuges). They are basically modified hot water extraction aided by diluent or solvent.

Figure 4-9 ASTCO PROCESS



2.4.1 Dravo Solvent Extraction

The Dravo Solvent Extraction Process was developed by Dravo to process oil sand on a large scale. The process consists of six steps:

(1) Oily sands are mixed with solvent and bitumen (micella);
(2) Fines are separated from the micella in a classifier;
(3) Fines overflowing the classifier are settled and washed with solvent;
(4) Bitumen and solvent are evaporated;
(5) Sands in the underflow are washed in a "percolating" bed extraction and
(6) Drained, washed sand is then steam stripped in a rotary kiln.

Dravo failed to respond. The process is very complex and likely uneconomical at small scale. For reference, a Dravo Process Flow Diagram is attached as Figure 4-10.

2.4.2 SESA Process

The Solvent Extraction - Spherical Agglomeration (SESA) Process was developed by the National Research Council and is currently marketed by Terra Energy Ltd. The SESA process consists of a patented vessel with a ball mill, agglomerating and wash cone sections. The ball mill section breaks down the feed and contacts it with water and solvent. The agglomerating section consolidates the sand and the wash cone washes the agglomerates with solvent which is recycled from the agglomerate rotary kiln dryer operating at 110°C. Bitumen and solvent are clarified to reduce solids and water. Solvent is recovered by distillation. Basically, spherical agglomeration is a process whereby finely divided solids suspended in water may be separated from the water by mixing a small quantity

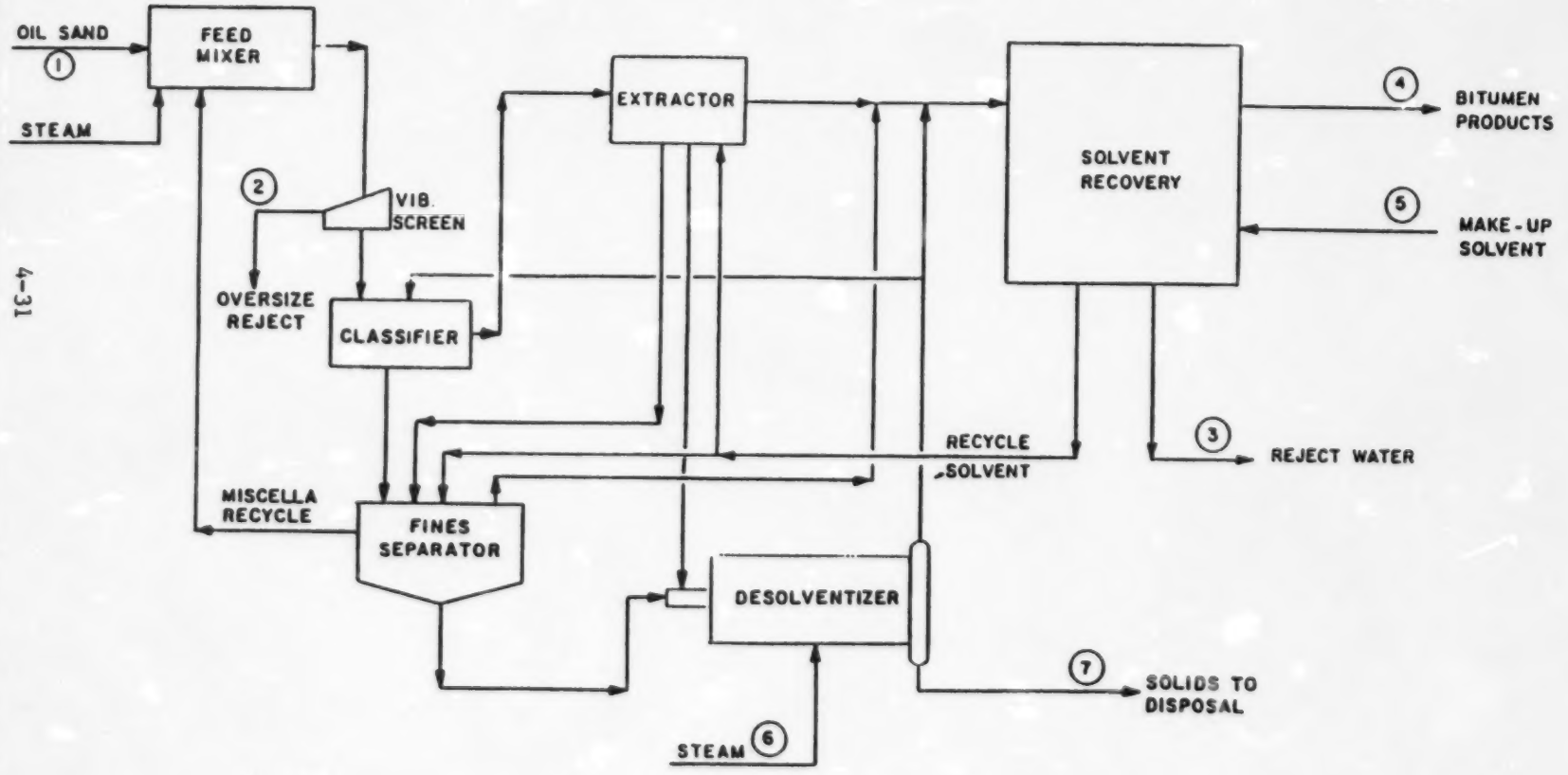


FIGURE 4-10 Dravo Process Flow Diagram

of solvent (immiscible in water) with the slurry. Continued mixing leads the solid particulates which have become coated with solvent to collide and adhere. The resulting agglomerates are of sufficient size to be screened from the water. The solvent is then recovered from the solids in a rotary kiln. Diluted bitumen is recovered in a clarifier and is composed of 1/3 bitumen, 2/3 solvent, 2% solids and 1% water. Solvent loss is claimed to be less than 0.5% and bitumen recovery is 92-96%. The process has only been bench scale tested. No economics were presented. However, the development cost of the unit would still be substantial. The process faces the same problem as all solvent processes in that clays may absorb solvent which can only be recovered by high temperature retorting.

Figures 4-11 and 4-12 show the processing scheme.

2.4.3 Solv-Ex Process

The Solv-Ex Process developed by Solv-Ex of Albequerque, New Mexico is totally solvent extraction from the initial separation vessel. Oily solids would be fed by conveyor to a "log washer" which mixes hot water with the solids and frees the oil droplets. Two stage counter current separation cells, with diluent being added between the stages, separate the oil and water/solids slurry. The first stage produces a clean oil and the second stage, clean tailings. The coarse tailings are then dewatered in a screw classifier and the fine clay slurries thickened in a conventional thickener. Clarified water is heated and recycled. The sludge from the thickener underflow is further de-oiled in the vacuum steam stripper followed by a solid bowl centrifuge.

The process must be designed to explosion proof specifications. Clays affinity for diluent makes it very difficult to recover the solvent from the sludge. The use of many pieces of equipment with high wear such as centrifuges makes the process

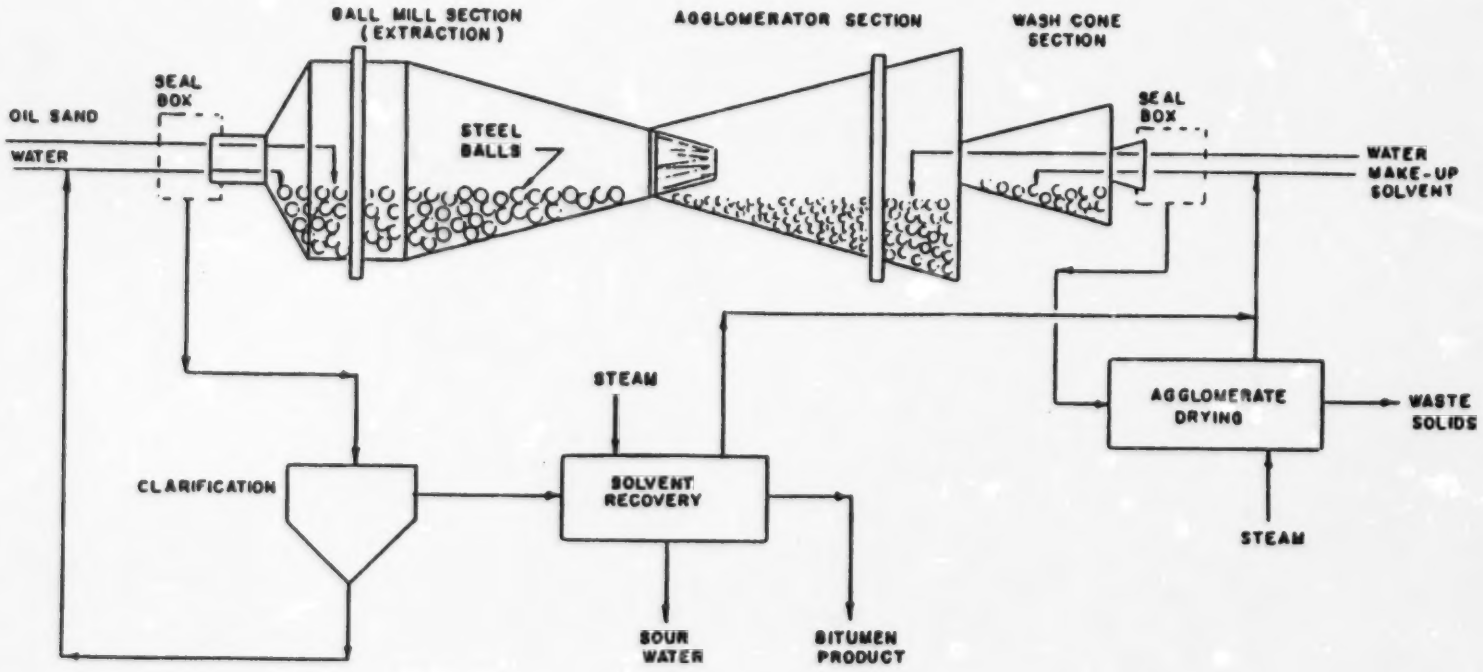


FIGURE 4-11 SESA Single Stage Process Flow Diagram

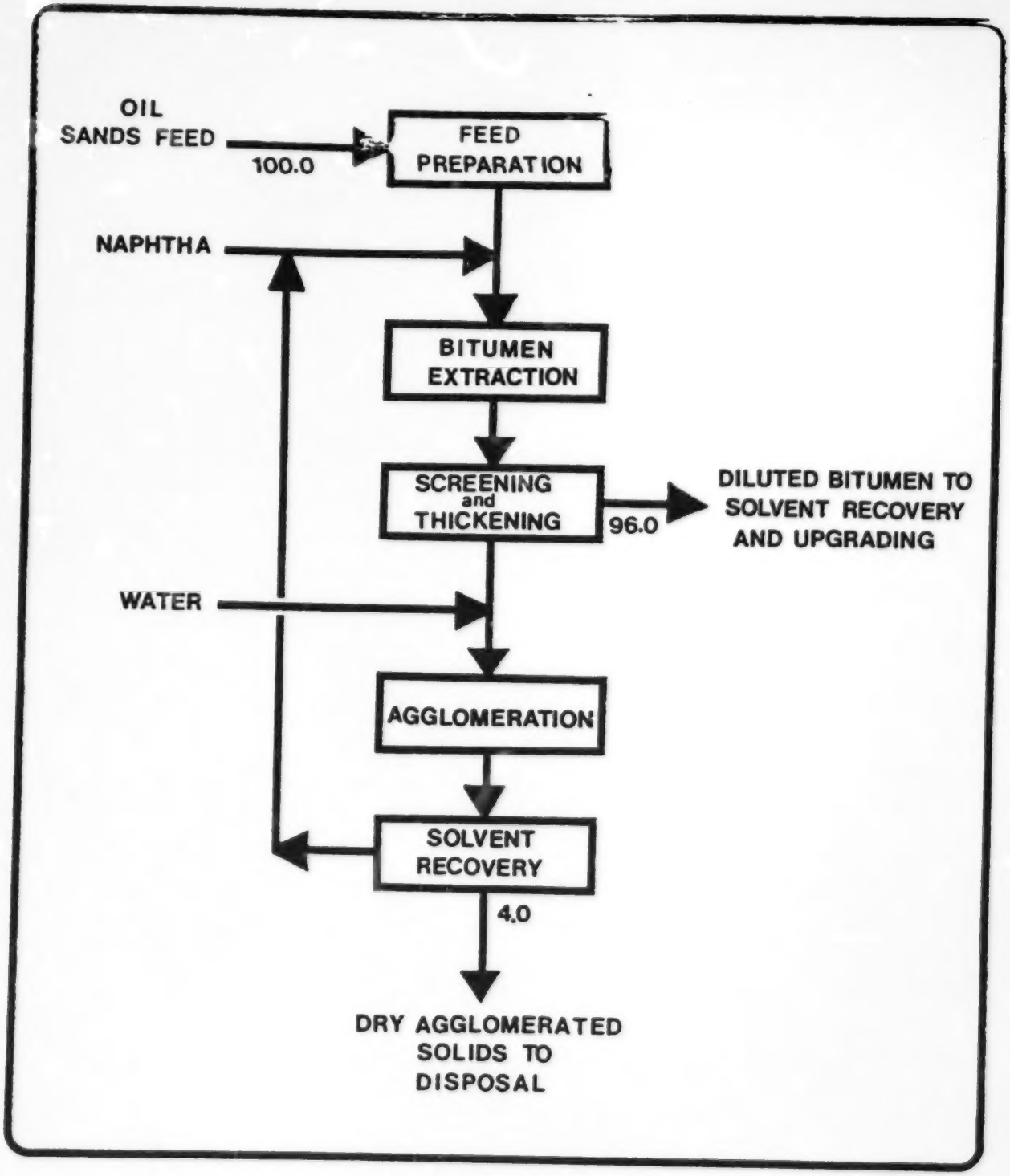


FIGURE 4-12

BITUMEN RECOVERY FROM OIL SANDS BY THE SESA PROCESS

Figures Indicate Per Cent Bitumen Distribution with a 12 Per Cent Oil Sands Feed.

complex and difficult to operate. Solvent losses in high clay situations would be high, resulting in a final disposal problem. The overall capital and operating cost of the process would make it non-competitive with other simpler processes. Solv-Ex did not respond. For further process reference see Figure 4-13.

2.4.4 RTROSA Process

The RTROSA/GULF process is a modified hot water extraction process which uses a patented contractor to mix oily sand with diluent, followed by an oil/water separator and secondary thickener clarifier. Overall, the process is based on a sludge conditioning step followed by dilution centrifuging. During conditioning in the contractor, surface tension modifiers, wetting agents and other chemicals are added. High viscosity heavy oil is diluted. The diluted bitumen is then separated in a solid bowl centrifuge. Solids are discharged at 20-30% moisture. Water and hydrocarbons are recycled to the existing field treatment facilities. The emphasis in this process is placed on the feed preparation (conditioning) which ensures the successful operation of the centrifuge. The major innovations of this process are the emphasis ascribed to the characterization of the feed and the flexibility of the conditioning stage to accommodate feed of variable composition and with high clay content. Tests indicated that the process will produce a treated thickened sludge of less than 0.5% hydrocarbon.

The process was sized at 1.3 m^3/h. The cost was $757 000 capital and $\$6.81/m^3$ to operate. No operation should be required beyond those in the existing plant as per their 1985 paper.

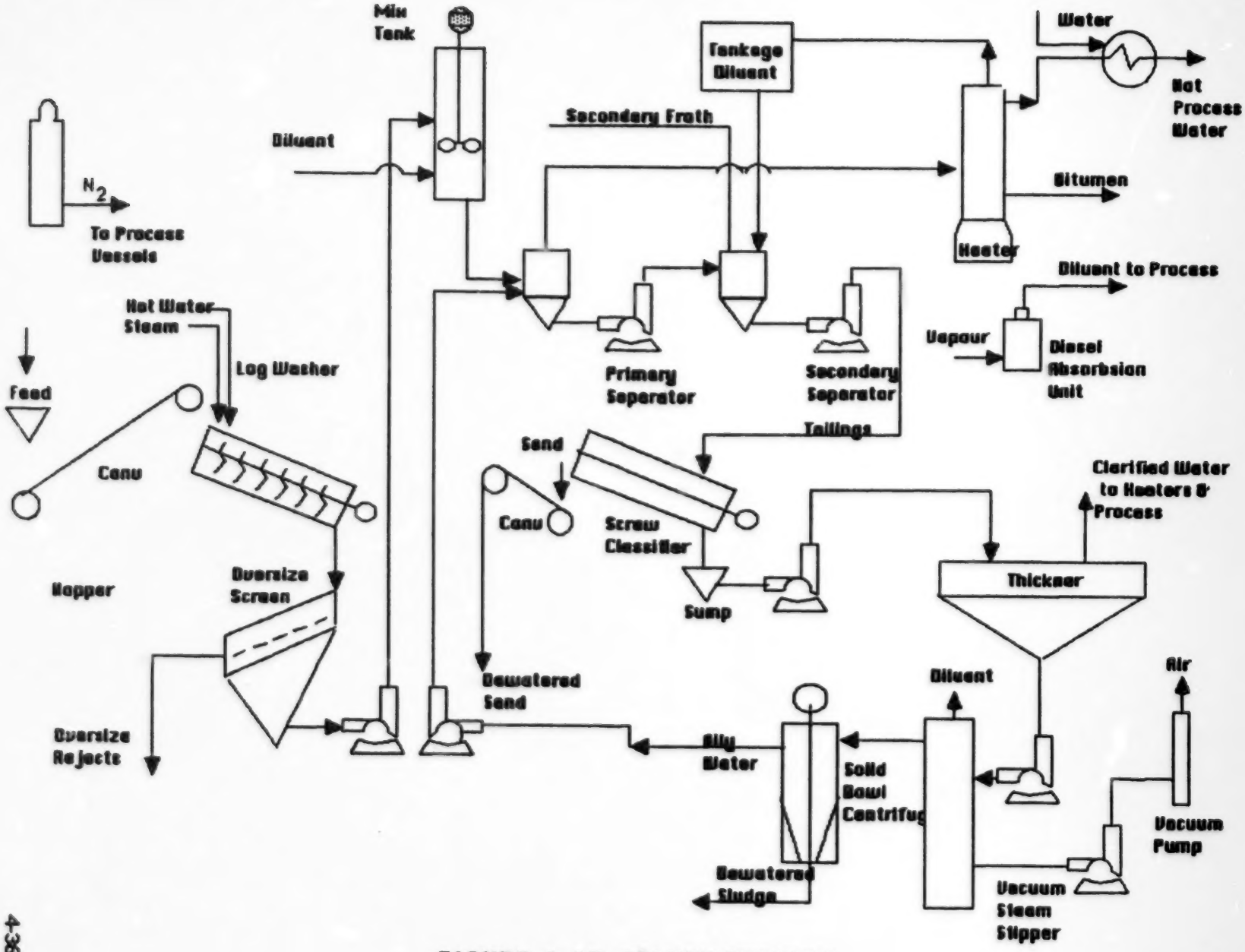


FIGURE 4-13 SOLVEX PROCESS

R216J01

The cost information submitted along with the paper suggested a 100 L/h unit for Pelican Lake would have a capital cost of $540 000 and an operating cost of $200 000/yr to process 3 180 m^3 of sludge (ie. $62.90/$m^3$, cradle to grave).

The only disadvantages of the process are the high hydrocarbon in the sludges and the diluent which may be absorbed with the clay. Any diluent loss may add aromatics to the disposed solids. Advantages are the simplicity, low cost and ability to process high clay sludges, tank bottoms, etc. In addition, the RTR process can incorporate a flotation system and thereby reduce the hydrocarbon in the discards to less than 0.5%. They are a well funded company, anxious to do business in the area of oily sludge cleanup.

2.4.5 Agloflotation Process

The Agloflotation process developed by the Alberta Research Council uses coal to soak up oil from oily sand and forms agglomerates in a slurry. The process begins with a run of mine coal and raw oily wastes such as oily sludges from tank bottoms, ecology pit wastes, wastes from industrial spill sites, and produces three product streams: combustible coal/oil fuel (adsorption of oily wastes onto coal), cleaned solids, and water from flotation.

The claimed advantages of the process are the following. Mechanical energy inputs are kept to a minimum and the process produces a stable hydrocarbon product at acceptable residual hydrocarbon levels of less than 0.3%. Four years of research and approximately 400 tests demonstrate the process workability. The plant is mobile.

The disadvantages of such a process are the following. Some 92 tpd of coal is needed to process 5 tpd of oil. Economics may require an assumption that revenue from sale of coal/oil hydrocarbon product is equal to initial cost of acquiring coal. Further treatment is required of non-condensable vapours and particulates. The oily agglomerates will be sticky and slump in the summer and freeze to the trucks in the winter. They will not be an ideal fuel. Transportation costs will be high, and the owner of the process plant will need to market the coal agglomerates.

The utility requirements are hot water or condensate, utility water/cooling water, coal or natural gas, and a frother.

A conceptual diagram is shown as Figure 4-14.

The cost of a 100 TPD mobile plant is outlines as follows:

Capital Cost Estimate

o Major equipment purchase price	$ 913 K
o Freight (@ 5% of equipment purchase price)	46 K
o Water tanks	50 K
o Installation (includes piping, electrical, structural)	675 K
o Trailers for equipment	147 K
o Re-useable free-standing building	165 K
TOTAL DIRECT COST	$1 996 K
o Engineering and construction expenses (15% of total direct cost)	$ 299 K
o Contingency (20% of total direct cost)	399 K
TOTAL PLANT COST	$2 694 K

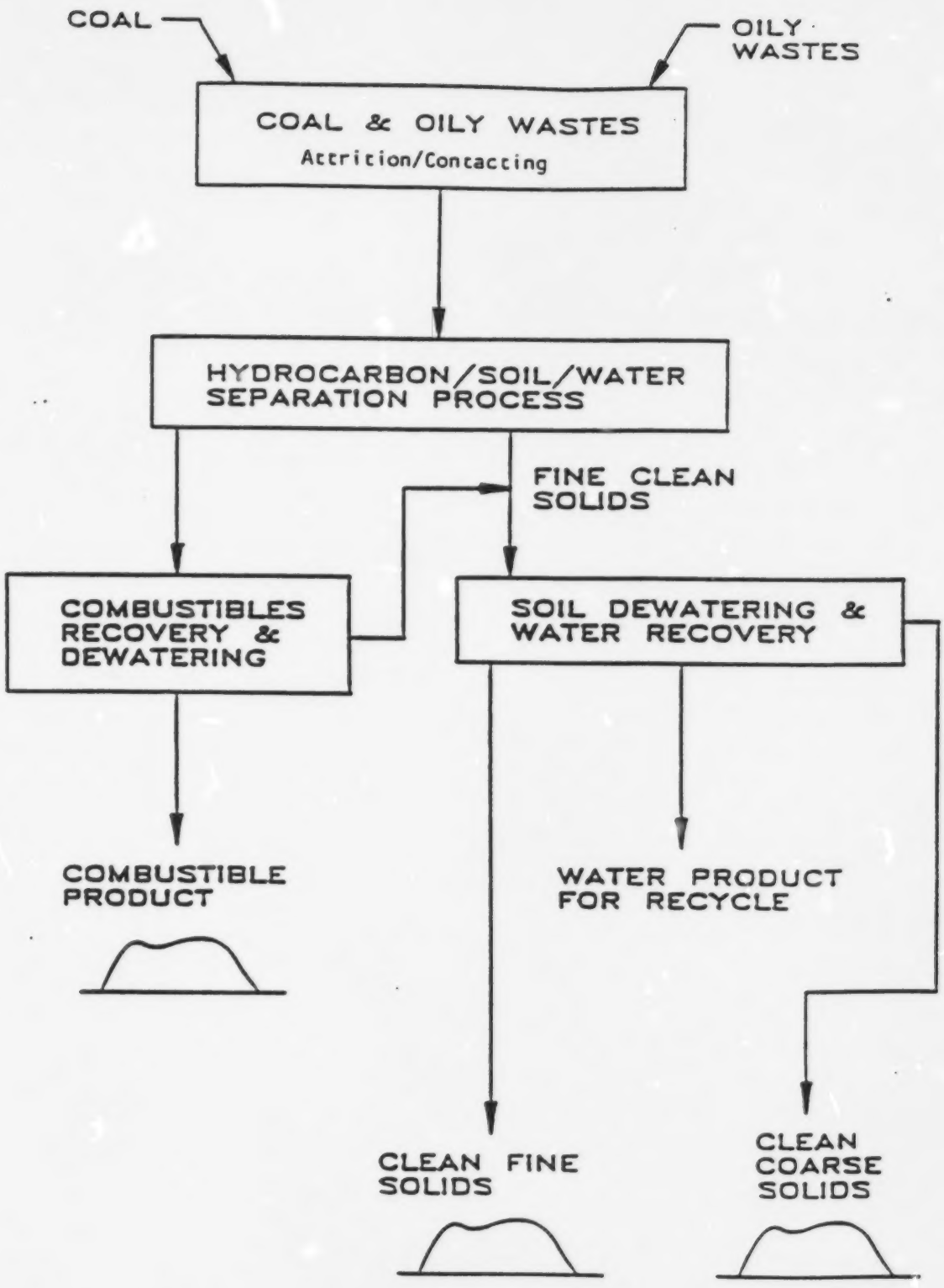


FIGURE 4-14 Conceptual Block Diagram of the AGLOFLOTATION Oily Wastes Clean-up Technology

Operating Base

o	Operating hours:	7 200	
o	Plant utilization:	0.82	
o	Soil feed (t/h):	5.00	
	(t/yr):	36 000	(27 692 m^3/yr)
o	Coal feed (tpd):	92.00	
o	Oil feed:	Nil	

Operating Costs

o	Capitalization (3 year straight line depreciation)	$ 898 K

Other Operating costs

o	Site Costs	
	- Emergency dump pond	$ 16 K
	- Foundations for thickener	15 K
	- Trailer hookup	60 K
Total site costs		91 K
o	Operating labour	632 K
o	Chemicals (16 556 kg of reagent @ $5.51/kg)	91 K
o	Electricity (2.10 MW @ $0.045 kW)	95 K
o	Maintenance (6% of total direct cost)	120 K
o	Miscellaneous supplies (@ 0.75 % of total direct cost)	15 K
o	Front-end loader rental	206 K
TOTAL OPERATING COSTS		$1 250 K

The process will not likely operate more than 6 000 h/yr and will cost $77.60/$m^3$ for the first 3 years and $45.14/$m^3$

thereafter (using ARC figures) or $93.12 and $54.17/m^3 using the 6 000 h/yr basis which is more common for plants of this nature.

2.5 CHEMICAL PROCESSES

2.5.1 Neutralysis

NEUTRALYSIS Process submitted by Energy Consulting Inc. utilizes pulverized municipal waste "mixed with sewage sludge, oil field sludge, grease trap sludge, or other sludge, etc. and clay." The feed is then extruded and dried in a rotary kiln. The resulting product is a light weight aggregate which is used in the manufacture of light weight concrete bricks or decorative fill. The process has been tested and is in the final stages of permitting in Michigan.

The process could be amenable to accepting oily sand and sludges as a feed stock, however, it would require a central facility, marketing, etc. to establish a whole new industry.

2.5.2 Ekopor V-D2 Utilization

Ekopor V-D2 is a chemical that can be added to an oily slurry, allowing the oil to be selectively absorbed and separated from the water. Twenty grams of the chemical will granulate 100 ml of oil. The absorbed solids can then be used as a fuel. No economics were presented.

2.5.3 Citri-Solve Application

CITRI-SOLVE supplied by Envirodyne International is a chemical spray applied to oil spills for about 10 - 20 minutes which digests the oil. The material is then "washed away" or vacuumed. The product is hazardous and the resultant material must still be disposed of. It is not suitable for oily sand applications.

2.5.4 O.S.SEP Process

The O.S.SEP Process utilizes innovative and proprietary composition of non-toxic chemicals to resolve stable emulsions and to facilitate separation of hydrocarbons from solids and water.

Figure 4-15 shows the processing scheme.

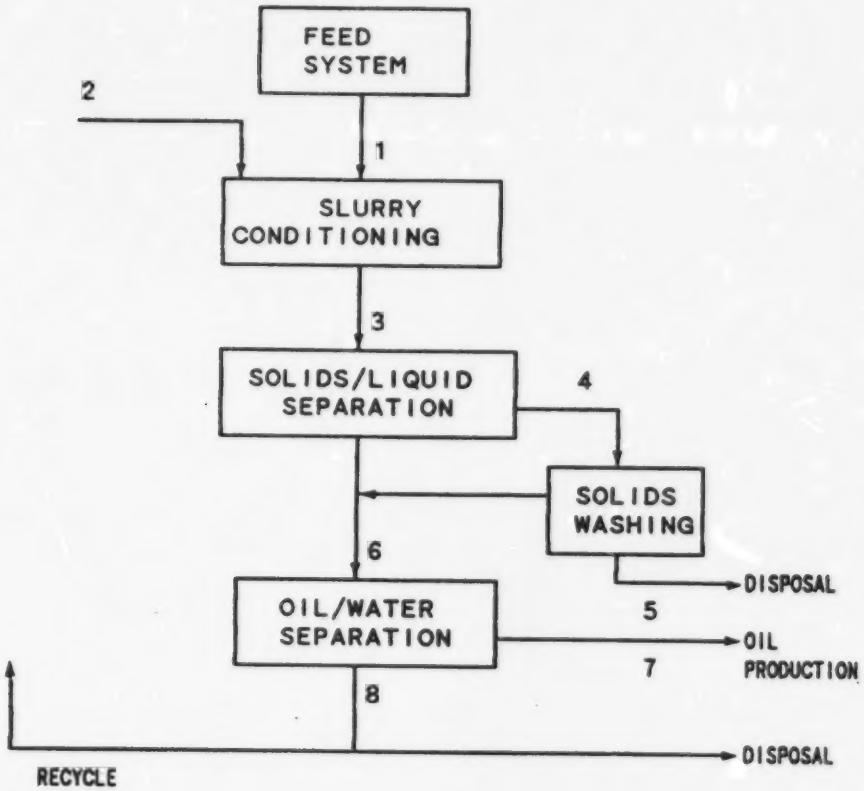
The process is carried out in an aqueous slurry at 60°C to 80°C, mostly under atmospheric pressure. The slurry concentration and the dosage of chemicals (100 to 1000 ppm) varied depending largely on the feed composition. The bulk of the process water can be recycled to same on heating and chemical costs. Modified commercially available equipment, recently developed in the mineral processing industry, is used to separate the solids from the liquids and the oil from the water. The equipment features no moving parts (obvious exception are the mixing and transfer pumps and the clean solids conveyer belt) requiring low maintenance and operating costs.

Development background: the O.S.SEP. Process combines several innovative process research and development works, initiated in 1983, with commercially proven technologies and equipment. Extensive laboratory testing have demonstrated the outstanding capability of the chemical process to separate a wide-ranging selection of oily solids wastes. Samples tested includes:

Tank bottoms;	Kitscoty - Mobil Oil
	Pelican Lk. - Gulf
	Wolf Lk. - B.P.
Tailings;	Ft. Mc. - Syncrude
Pit sludge;	Wolf Lk. - B.P.
	Pelican Lk. - Gulf

FIGURE 4-15

O.S.SEP. PROCESS BLOCK FLOW DIAGRAM



MAJOR STREAM	1	2	3	4	5	6	7	8
FLOW,T/H	5	20	25	4.9	4	23.1	3.7	19.3
BITUMEN,%wt	20	0.1	4	3	0.5	4.3	26	0.1
SOLIDS, %wt	70	0.05	14	69	85	0.5	3	0.05
WATER, %wt	10	99.8	82	28	14.5	95.2	71	99.8

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CALGARY *ALBERTA*

Desand sludge and slop;	Celtic - Mobil
	Battrum - Mobil
	Lloyd. - Mobil
	Elk Pt. - Amoco
	Cold Lk. - Esso

In 1989, the efficiency of the chemical process to clean produced solids from Peace River plant was demonstrated. Products samples were sent for analyses to verify compliancy with environmental and regulatory requirements.

Capital installation costs of a skid mounted portable plant, 5 tph capacity is estimated at $0.9 million (Calgary location, 1990).

The breakdown costs of the constructed modules and other equipment are:

Feed system;	$160 K
Conditioning system;	100 K
Solids/liquid separation;	60 K
Solids washing;	150 K
Oil/water separation;	180 K
Pipe and fittings (intermodules);	40 K
Tanks, water and oil storage;	25 K
Tanks, chemicals and mixing;	15 K
Controls and computer system;	90 K
Crew trailer, office/lab;	60 K
Tools and miscellaneous;	$ 20 K

Operating costs estimates are based on seasonal work period of five months; 150 days at 80% capacity. The plant operates continuously (24 h/d) requiring four shifts of three operators, one plant supervisor and 20% management time. Credit for the product oil is assumed to balance the cleaned solids disposal costs and the feed waste transport costs to the plant, located in a central location.

The total annual operating costs of the plant is estimated at $0.717 million. The breakdown is as follows:

Capitalization, 20 yr. on 10% int.;	$ 100 K
Operating labour @ $25/h, include;	315 K
payroll charges & management time	
Chemicals & consumables;	20 K
Utilities, steam @ $7/1 000 kg;	22 K
electricity @ 2.8/kW	
water @ $.10/$m^3$	
Maintenance, 5% factor;	45 K
Replacements;	25 K
Contingencies;	35 K
Rentals, vehicle etc.;	10 K
Overhead @ 50% of labour.	$ 145 K

Processing cost based on annual operating cost of $0.62 million and capitalization were straight line method with 3 year total write-off would amount to approximately $38/t or $49/$m^3$. It is an attractive, proven chemical process.

2.5.5 Oilfield Produced Oil Sand Deoiling System

Shell Canada has developed a method to clean-up oily produced solids sludges and storage tanks bottoms. The separation process consists of three steps.

1) Conditioning oily produced solids with an appropriate chemical to change the surface wettability from oil-wet to water-wet.

2) Gravity separation and/or gas flotation to recover hydrocarbons.

3) Dewatering of the treated solids by conventional means such as cyclones, screens.

Based on preliminary analysis the treated solids would contain fine sand and silt and could be disposed in a suitable landfill.

Because this technology is presently at the development stage, detailed information is not yet available. Further testing could provide valuable data for evaluation of this technology in the near future.

Shell Canada can design their system into two different configurations. Figure 4-16 represents a stand alone facility while Figure 4-17 represents an integration of this system with an existing process.

It should be noted that the Shell technologies were not included in the Kepner-Tregoe analysis due to late receiving of submission.

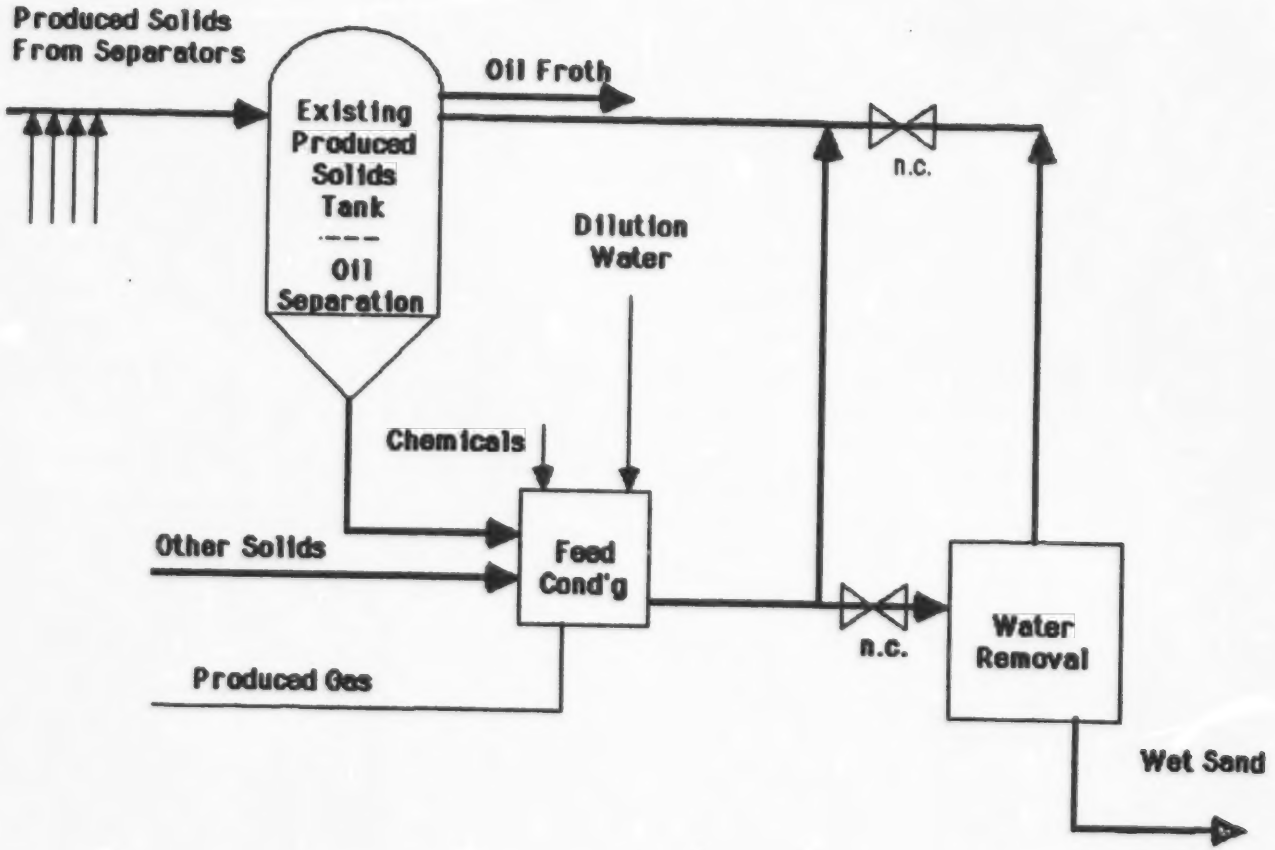


Figure 4-16 Oilfield Produced Oily Sand Deoiling Facility
Stand Alone Facility

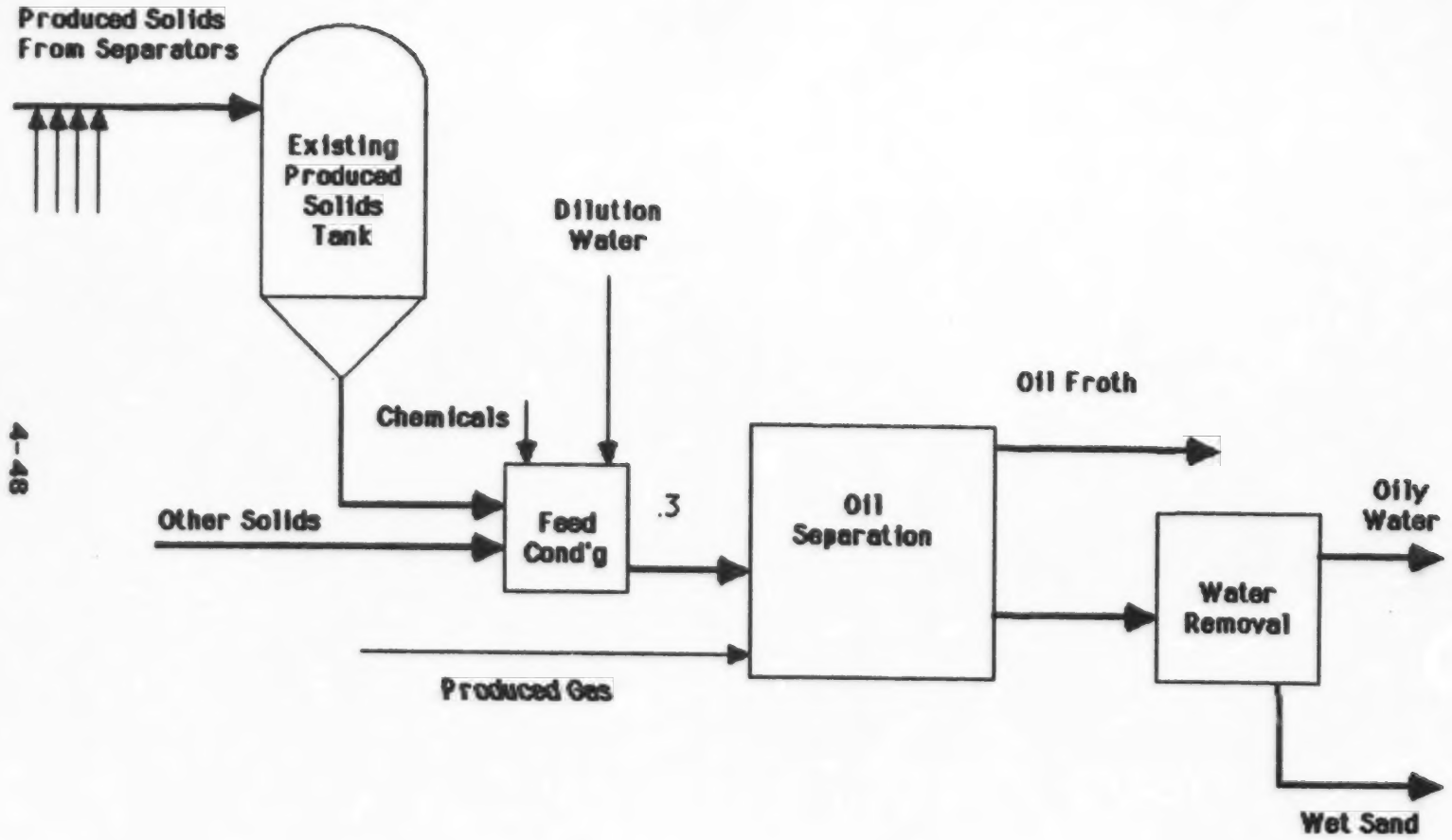


Figure 4-17 Oilfield Produced Oily Sand Deoiling Facility
Integration With Existing Produced Solids Facility

2.6 OTHER PROCESSES

Other process are those which do not fit the previous categories, such as centrifuging and filtering.

2.6.1 Guinard Centrifugation

The Guinard Centrifugation process submitted by Petrocycle proposes to use a nozzle bowl centrifuge (similar to those used in Fort McMurray as second stage froth cleanups units - ie. Alpha-Laval and Wesphalia) to separate hydrocarbon and water from the solids.

The process as shown in Figure 4-18 consists of:

- pumps to extract the product and subsequently to pump it into the treatment unit;
- a steam heated tank (60°C);
- a self-cleaning filter which enables the elimination of the large solids (these solids may cause the blockage of the separator);
- an injection device for chemicals/emulsion breakers;
- a heat exchanger for re-heating (up to 100°C);
- the separator (centrifuge);
- reception tanks for the three separated output phases and evacuation of these tanks by means of pumps;

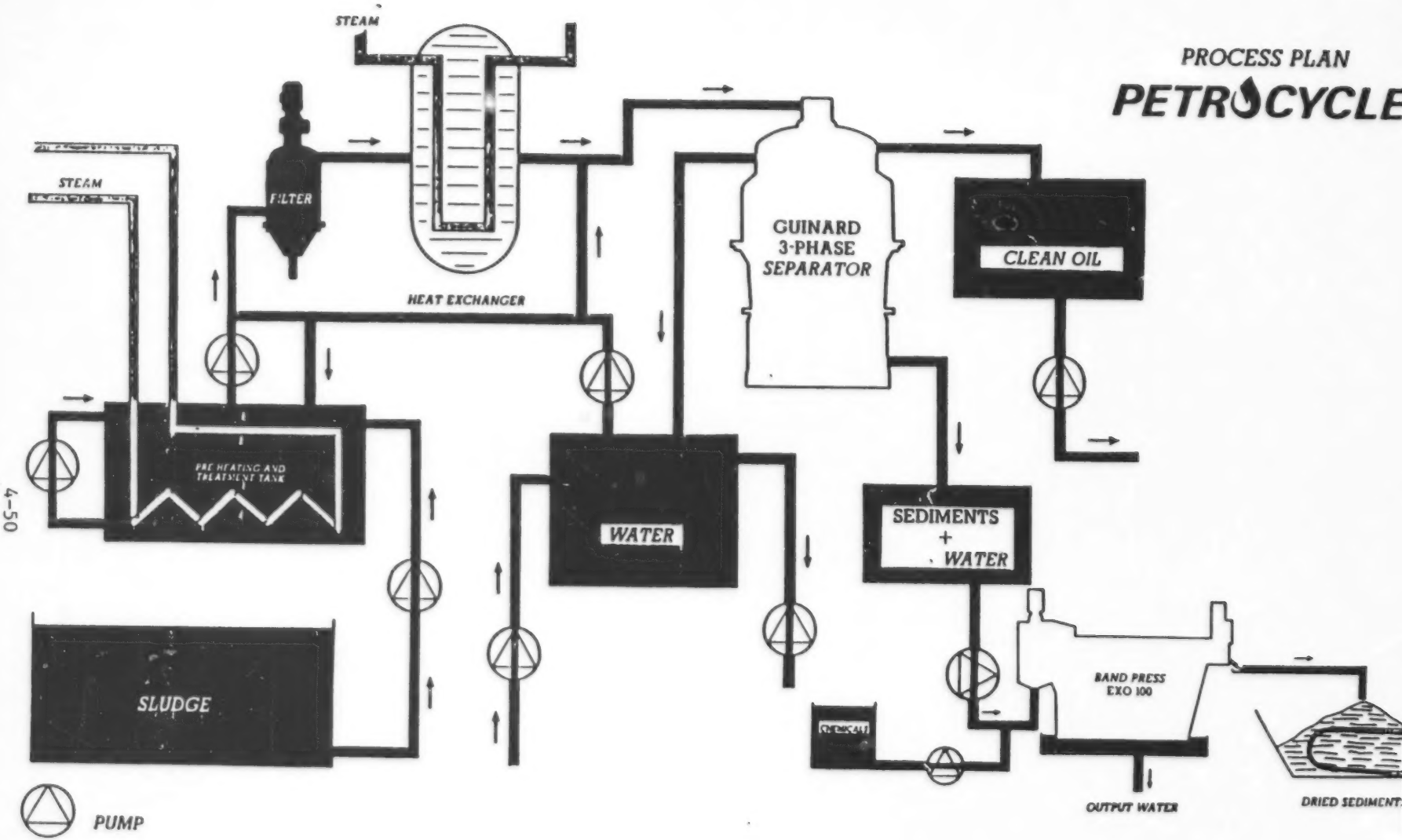


FIGURE 4-18 Guinard Centrifugation Process

- o equipment to recycle the water for rinsing the different parts of the process;

- o independent means for the maintenance of the separator and other equipment;

- o electric and electronic unit controls and equipment.

There is also a separate filter band machine plus polymer additive system which removes a large part of the water content of the sediment phase.

The claimed product oily phase contains less than 1.5% BS & W (Syncrude & Suncor only make 5.5% with two stage centrifuges) and less than 5% hydrocarbon in the solids (similar to Syncrude & Suncor first stage BIRD centrifuge).

The main disadvantages of this process are the need for a high wear self cleaning filter, and high "g" high wear centrifuges which have been proven costly to operate in Ft. McMurray.

2.6.2 Bird Solid Bowl Centrifuge

The BIRD sludge cleanup process presented by Bird Machine of Canada is similar to the above Guinard process and to that employed by Suncor and Syncrude in that the oily slurry is heated, centrifuged in a solid bowl centrifuge then the oil is polished in a nozzle bowl centrifuge. The nozzle bowl (disc) centrifuge is not preceded by a filter which would render it ineffective in the Ft. McMurray application where coarse sands and fibers would plug the nozzles.

As with the above process, the application is incorrect for this type of feed materials.

2.6.3 Miscellaneous Filtration Methods

A collection of brochures on Filtration was submitted by Wawashkesh Sales Agencies Ltd. They included the walnut shell "In-Depth Filtration System" which is claimed to remove 95 to 98% of suspended solids and 90 to 95% of the hydrocarbons. The process probably has downstream application but is not likely to be suitable for oily solids cleanups as presented herein.

3 DISCUSSION OF TECHNOLOGIES

The technologies presented in Section 2.0 indicate a wide range of processes are available for the processing of oily solids. On a large scale, Syncrude and Suncor already process oil sand to the limits of economics. Some of the technology proponents claim to be within the realm of economic viability. However, when all of the components of a "cradle-to-grave" process are considered, few would be judged economical on a stand alone basis. The alternative, then, is to choose those that produce environmentally acceptable solutions to the cleanup and disposition of oily solids. Each category of process has its own drawbacks which present risk as to the "finality" of the disposition possibly with the exception of reinjection or salt cavern disposal.

High temperature processes burn the hydrocarbon component of the oily solids, leaving a coke residue on the sands (sometimes black in colour). The heavy metals are either sent air borne up the stack or left with the spent sand along with the salts. These heavy metals and salts will eventually leach out of the land fills into the groundwater. Whether they present an environmental hazard is a matter of conjecture. Geologically, heavy metal deposition via leaching takes place all of the time in nature. Stack gasses can be scrubbed, however, some particulates will still be emitted along

with small quantities of SO_2, NO_x and CO_2. The effluent will, however, meet current environmental standards. Pyro-processes tend to be an expensive (capital and operating cost) approach to oily sand cleanup with the exception of a single fluid bed combustor. In applications to oily solids containing less bitumen, they may also require natural gas or other supplementary heat to sustain combustion.

Road surfacing allows the oily sand and waste oils to be spread on country roads. The mixing and packing techniques developed by Esso at Cold Lake and the SaskAlta Waste Disposal Cooperative result in improved gravel roads (although somewhat slippery when wet) with only minor leaching and migration of the hydrocarbons. The salt water from the produced oily sands can be decanted and reinjected in the lower geological formations which are already very salty. The long term effects of spreading this oily waste are not yet known and are of obvious concern in considering a "cradle-to-grave" approach to disposal.

Hot water extraction processes clean most of the hydrocarbon from the sands leaving less than 0.5% oil with the sand. Salt water is recycled and can be disposed of in deep wells. Hydrocarbon is recovered and blended into the product. Over time the residual oil is likely biodegradable and will leach very slowly from engineered land fills. Relative to road surfacing the processes can compete economically as far as operating cost is concerned. They do require capital (less if the process is incorporated into existing plants). The produced oily sludge (clays and emulsions) from the processes are being spread on agricultural fields in southern Alberta to help retain water and reduce dusting and soil loss. Crops seem to thrive in reclaimed areas. The long term effects of trace heavy metals has not been studied. Some commercial fertilizers do contain trace elements, as they are

essential to some extent for all living things. Alberta Government regulatory guidelines at present have a 6% oil-in-solid limit for land fills. However, other provinces such as Quebec has recently imposed a 0.1% limit on soil reclamation. Improvement on Hotwater Extraction Process is therefore required.

Solvent extraction processes will ultimately strip more hydrocarbon from the sand, but the presence of clays will lead to absorption of hydrocarbons and organics within the clay minerals. Solvents tend to be more hazardous and will argueably increase the final disposal problem. Since the equipment in such plants must be explosion proof, and the solvent must be recovered, solvent extraction processes are more expensive (both capital and operating cost) than hot water extraction processes and likely no more effective. The risk of increased hazard due to solvent in the land fills and the increased costs would tend to eliminate solvent extraction as a viable approach to oily solids cleanup.

Chemical processes are also numerous with varying degrees of success. Chemical emulsion breakers will improve the hydrocarbon product and likely be acceptable in the oil phase with no presence in the water phase. Chemical processes which combine the oil and solids with other materials resulting in light weight aggregates, would require a new industry which would be dependant on oily solid production and therefore be somewhat risky. As the oily solids are cleaned up in the future, the new industry would lose its feed stock. If the chemical product were to decompose in the future, the hazard would be wide spread. Products that combine with oil, must still be impounded or disposed of in some manner which presents environmental risk. Combustion and the resulting air pollution with the added chemical components and metals will not be any less risky or expensive than pyro-processes.

4 TECHNOLOGY SCREENING

Technology screening was accomplished by reviewing processes submitted by the various proponents and discussing their technology with respect to oily solids cleanup requirements. Plant sizes of 1 m^3/h and 10 m^3/h were established as capacities applicable in todays operating and economic environment. A list of "must" and "want" criteria was drafted so that technologies could be compared on an equal basis. The list was jointly weighted according to the needs of the Canadian Petroleum Association operators. A Kepner-Tregoe analysis was then done to select the most promising technologies for this application.

4.1 TECHNOLOGY SELECTION BY KEPNER-TREGOE ANALYSIS

The purpose of the screening study was to decide upon up to four of the potentially most successful processes for cleanup of oily solids at rates of 1 m^3/h and 10 m^3/h. This decision would apply to large and small operations as well as the possibility of a regional cleanup facility. A secondary objective of the process would be to clean tank bottoms, slop oils, spilled oily solids from process or well sites, and any other potentially environmentally sensitive oily solid wastes. These secondary considerations were weighted lightly compared to the primary objective. As an example, hot water extraction requires only mild agitation (low energy input) to recover oil from oily solids. However, tank bottoms, sludges, slop oil and spill oil would require vigorous conditioning (high energy input) to recover most of the oil from the solid and water phases. Additionally, current practice of road surfacing and oiling would be used as a basis to evaluate economic viability. Recognizing that the heavy oil business has a very low profit margin, oily solids and waste cleanup should be economical, simple and effective.

The expected results of the study are that the process must be supported with "Materials Handling, Transportation, Utilities, and Final Disposition" so that oily solids and wastes are processed from "Cradle to Grave" with environmentally acceptable final disposition. The process should represent as little risk to the operator as possible. The process site should be "Stand Alone", although the utilities requirement may ultimately be supplied by a central existing heavy oil production plant. Therefore, the process utility requirement will weigh heavily on the choice if expensive utilities are needed to support the process.

As a result, the musts and wants of the project along with their weightings are as follows:

MUSTS:

The technologies and their proponents must:

- Be able and committed to participate in a field evaluation program;
- Be capable of commercializing and marketing the technology;
- Identify health, safety and environmental problems of concern with their process;
- The "whole" process must be "Cradle-to-Grave". There cannot be additional disposal problems associated with the discards.

WANTS:

The technologies and their proponents should satisfy the following wants:

- Capital and Operating Costs should be competitive with current road surfacing practices costs of $\$70/m^3$;
- The technology should be "Proven" to the extent that it has at least been bench scale tested and preferably field tested in similar application;
- The process should be adaptable to operate at 1 m^3/h or 10 m^3/h and should be expandable;
- Scale-up to commercialization should be straight forward;
- The process should be simple, flexible, easy to operate and easy to maintain;
- Products and residual streams should be easily disposed of;
- Safety and Health should not be at risk;
- The process should be more or less mobile and able to operating in all weather;
- The process should be capable of being incorporated within an existing heavy oil plant or added on to an existing plant;

- Materials handling should be relatively straight forward outside the process battery limit (i.e. it should not have unusual materials handling constraints);

- The Developer should be capable (i.e. experienced with process development and field testing, have experienced staff available, be financially sound and be reasonably familiar with Alberta and Saskatchewan heavy oil operations and regulations);

- The residual products should produce clean sand of 0.4% oil. The water phase should contain less than 1500 ppm salts (chlorides). The spent sands should not contain leachable heavy metals;

- Utility consumption and cost should not be excessive.

Table 4-1 summarizes relevant technologies which were submitted to the Project for evaluation. Kepner-Tregoe analysis table used in the analysis session is included as Table 4-2. The three selected technologies:

- STS Process (Section 2.3.5)
- Fluid Bed Combustor (Section 2.1.2)
- Re-injection (Section 2.2.4)

are to be evaluated further. Esso's road surfacing technology will be used as the "base case" for comparison.

TABLE 4-1

Relevant Processes/Technologies
submitted for a
Kepner-Tregoe Analysis

I. D. Number	Process/Technology	Proponent
T-01	Taciuk Processor (ATP)	AOSTRA/UMATAC
T-02	Fluid Bed Combustor	Pacific Environment systems
T-03	Dolen Burner	Environment Protection Co.
T-04	Anachemia Incineration	Keith Jackson
T-05	High Intensity Incineration	Trecan Combustion Ltd.
T-06	Superburn Revolving Fluidized Bed Incinerator	Canadian Waste Management Inc.
W-01	Oily Sludge Cleanup Process	Suncor Resources
W-02	Solids Treatment System (STS)	ASTCO Ltd.
S-01	SESA	Terra Energy Ltd.
S-02	RTR/Gulf Process	RTR Oilsands Ltd.
S-03	Agloflotation Process	ARC
C-01	O.S. Sep. Process	M. G. Engineering
C-02	Neutralysis	Energy Consulting Inc.
C-03	Citri-Solve	Envirodyne International
C-04	EKOPOR V-D2	(K. Palmer - Rep.)

TABLE 4-1

Relevant Processes/Technologies
submitted for a
Kepner-Tregoe Analysis

I. D. Number	Process/Technology	Proponent
F-01	Road Surfacing	Esso Resources & Sask-Alta
F-02	Oily Sands Impoundment	Arthur A. Voice Construction
F-03	Re-injection	Halliburton Services
F-04	Salt Cavern Disposal	Newalta Environmental Services Co.
F-05	Sand Injection	Mobil Oil Canada
F-06	Fujibeton Pollution Control Solidification Technology	Canadian Waste Management Inc.
F-07	VAM	Canadian Waste Management Inc.
M-01	Oil Separation	Skimmer Oil separators Inc.
M-02	Guinard Centrifugation	Bailey Int. & Petrocycle Inc.
M-03	Filtration	Wawashkesh Sales
M-04	Solid Bowl Centrifuges	Bird Machine of Canada

NOTATION

T: Thermal or High Temperature Processes
C: Chemical Processes
W: Hotwater Extraction
S: Solvent Extraction
F: Fixation Methods (e.g. Road Surfacing, Cavern Injection, etc.)
M: Miscellaneous or Other Processes

Table 4-2

KEPNER - TREGOE ANALYSIS
PRODUCED OILY SOLIDS CLEANUP TECHNOLOGIES

CPA FILE: AFE 89-6205-036
MONENCO: CPA 8601-2

TECHNOLOGY:

PROPONENT::

Date: 90-03-06

I D. No: _____

THE "MUSTS"	Yes/No
1. The Proponent is able and committed to participate in a field evaluation program	
2. The Proponent is capable of commercializing the technology	
3. The Proponent has identified health, safety and environmental problems of concern with their process or technology	
4 The whole process fits the "Cradle to Grave" approach and does not give rise to additional disposal problems with discards	

DOES THE TECHNOLOGY MEET ALL THE MUSTS FOR FURTHER EVALUATION ? _____

IF NO, ANY COMMENTS ? _____

_____

	THE "WANTS"		Weight Factor F	Absolute Score S	Evalution Comments & Notes	Weighed Score WS = FxS
#	ITEMS	ASSESSMENT MEASURES				
1	Capital Cost	Low - "Cradle to Grave"	8			
2	Operating Cost	Low - "Cradle to Grave"	9			
3	Technology Development Status	Proven, at least on a bench scale & preferably tested in similar application	8			
4	Process Sizing	Adaptable to operate at 10 m^3/hr	6			
5	Process Configuration	Simple, flexible, good operability and maintainability	8			
6	Product Residual Streams	Readily disposable in an environmentally acceptable manner	10			
7	Safety and Health	Not be at risk	7			
8	Process Plant	Mobile	6			
9	Process Plant	Capable of operating in all weather conditions	5			
10	Material Handling (Outside of battery limits)	Straight forward without unusal constraints	5			
11	Technology Proponent	Capability in process development field testing, financing & staffing and familiarity with heavy oil operations & regulations	8			
					TOTAL WEIGHED SCORE	
					RANKING	

CONCLUDING REMARKS

IS THIS TECHNOLOGY SELECTED FOR DETAILED EVALUATION ? _____, OR

FURTHER ACTIONS REQUIRED: _____

_____

4.2 CONCLUDING REMARKS ON THE SELECTION PROCESS

Several noteworthy remarks can be made at the conclusion of this Section IV.

The Kepner-Tregoe analysis as a well-established decision-making methodology is characterized by its

- ability to average out conflicting opinions and interests of the participating parties, and
- result as a group decision of all parties concerned.

It is, however, an objective process with subjective input to the joint decision making.

AOSTRA Taciuk Processor

In a post-K-T analysis discussion, concerns were raised as to whether the decided three technologies are in fact "superior" to the AOSTRA Taciuk Processor (ATP), or is ATP unduly penalized because of its abundant, public data - especially costs data. It was generally recognized by the PSC members and Monenco that ATP is a well-proven technology. And as such it is not a "New Technology" requiring further field assessment. The ATP can indeed be used as the base process technology in Phase III.

SECTION V

SELECTED TECHNOLOGIES

SECTION V

SELECTED TECHNOLOGIES

Having completed the Kepner-Tregoe selection, the proponents whose technologies were selected were asked to prepare a formal reply outlining their commercial plant and their approach to demonstration through a field test unit. This section deals with the commercial approach to large quantities of processed oily solids. The ASTCO plant would employ (2) 5 m^3/h mobile processors, the Fluid Bed Combustor would burn 10 m^3/h in a fixed fluid bed combustor, reinjection proposed by Halliburton would be done at multiple sites (10 - 15) each year and include about 4 000 m^3 per site, and road surfacing would be done locally near ecology pits.

1 S.T.S. SOLIDS TREATMENT SYSTEM

Alberta Solids Treatment Company Ltd. have submitted complete detailed information with respect to their equipment. A commercial operation would be similar to that already in use at Barnwell, Alberta. Two STS-1000 (6.4 m x 13.1 m x 4.9 m) treaters would be used in parallel to treat 10 m^3/h.

The STS-1000 unit is moveable, although it would require pilot cars and would face road restriction problems in the spring since it weighs 40 800 kg. The units would incorporate a special undercarriage so that wheels could be mounted right on the unit for moving. PREMAY would supply a special trailer to meet 75% road ban restriction and eliminate power line wire lifting.

1.1 PROCESS AND MECHANICAL SYSTEM DESCRIPTION

Alberta Solids Treatment Company Ltd. (ASTCO) submitted a proposal to design and build a hot water extraction, API separator which could clean the oily solids to 0.5% residual hydrocarbon in the solids and produce a pipeline quality hydrocarbon for recycle back to the heavy oil plant. The solids would be low in chlorides and acceptable for a Class II landfill. Processed water would be recycled or reinjected depending on the salt content. Solids or sludge would be delivered by vacuum trucks or tandem gravel trucks and dumped directly into the vessel through a 2" screen. Larger particles and lumps can be hosed hydraulically through the screen or shovelled off to the side. A ramp would be built at each site to allow direct dumping. However, a front end loader, Cat 936 has been included in the estimate to level out deliveries and facilitate uniform feeding.

Two process vessels cleaning 5 m^3/h each, would be utilized to keep the auxiliary equipment fleet fully utilized. The operation would be run from April through mid-October (28 weeks) on a 5 day per week basis. The annual capacity would then be 33 600 m^3 of oily sand and sludge. The vessels would be (13 m x 6.4 m x 4.3 m) deep with an undercarriage which would allow 64 wheels to be attached for moving the 40 800 kg vessel. PREMAY would supply a "gooseneck" and "dollys" designed to accommodate 75% road bans. Moves would require pilot cars and take 1 day for each vessel. The actual mechanical and physical description of the vessel is covered very well in ASTCO's submission.

Feed water and produced water would be stored in 64 m^3 tanks, and solids would be dumped into a stockpile for loading by the Cat 936 front end loader.

The feed to the plant would be scheduled in advance and a Cat 936 front end loader (F.E.L.) with a fleet of local trucks would load oily solids from ecology pits into 9.2 m^3 tandem trucks at 240 m^3/d, 5 days per week. The average haul length for this study was assumed to be 48 km. Plant move costs versus haul distances would have to be assessed in order to optimize the number of moves. For this study, 6 moves annually were assumed.

A packaged boiler and diesel generator would be mounted on a semi-trailer which would be moved easily from site to site. The boiler output would be 1.47 MW although, only 1.0 MW may be required by the process to raise slurry temperatures to about 77°C and to compensate for heat loss.

The cleaned solids would be trucked to a Class II landfill for final disposition.

A "cherry picker" (14.5 tonne) mounted on a tractor along with a Hi-boy would be available on the site for maintenance, mounting wheels on the STS's and moving tanks etc.

Three trailers would be located at the site to be used as offices, lunch room, lockers, tool crib, small warehouse and shop.

Manpower Requirement

The manpower required to operate the fleet including the two F.E.L.'s, boiler and site (excluding truckers) is outlined below. Truckers would be contracted on a "rig including operator" basis at $40/h per 9.2 m^3 unit. Vacuum trucks (6.1 m^3) including operators are also available locally at $66/h.

Site Manager	1 (person)
Logistics Coordinator	1

Boiler Operators (3rd Class Steam Tickets)	3
Cherry Picker Operators	2
F.E.L. Operators (3 on site, 3 remote)	6
STS Operators	3
Total Manpower	16 persons

Schedule

- 24 hours/day
- 5 days/week
- boiler operating 24 hours/day
- 4 - 5 weeks/site
- 2 days to set up and move
- April 1 to October 10, 1991 (28 weeks)
- Min. 33 600 m^3 processed per season

1.2 RESIDUAL DISPOSAL

The processed sand containing less than 0.5 percent hydrocarbon and less than 1 000 ppm of chloride (generally much lower) would be dumped on the ground at the site, after dewatering to about 10% moisture on a drag conveyor or screw classifier, then loaded in contract tandem trucks for disposal at a Class II landfill.

A Class II landfill is one which "may not accept for disposal any liquid hazardous waste or hazardous waste containing free liquids, as well as the other hazardous wastes prohibited by regulation from landfill disposal". Class II landfills are constructed as follows:

- A site is selected which can be permitted and has a surface run-on run-off control system. Top soil and humic materials are removed with scrapers and stockpiled separately for future reclamation;

- A synthetic liner or 1 meter of clay (permeability of 1 x 10^{-7} cm/s or less) is placed under the containment area;

- The fill area would be surrounded by two sets of ditches, the outermost for preventing inflow of water and the inner ditch to collect site drainage. The site drainage (or leachate) would be monitored and treated to ensure that they meet surface water standards (drinking water quality);

- A groundwater monitoring system consisting of observation wells 200 m apart located in areas of hydraulic gradient (upgrade and downgrade) would be included. These wells would be completed such that they would provide an indication of the potential impact of the landfill or the upper water-bearing strata. The wells would be sampled and tested twice yearly according to environmental guidelines;

- The landfill will be constructed in 3 meter lifts (annually) to accommodate at least 10 years of waste (100 000 m^3). A Cat D-8 dozer would trim, compact the fill to prevent erosion, and control run-off;

- Each year a 50 cm clay shell would be placed over the lift;

- Upon completion of the landfill, 0.30 meters of top soil would be placed over 0.20 meters of clay in a small windrow fashion to allow material revegetation and to help retain moisture for sustaining growth;

- The site would then be seeded;

- For a period of 20 years thereafter, the site would be monitored;

- An excellent description of these details are contained in "Sask/Alta Waste Disposal Co-op Guidelines for the Disposal of Cleaned Produced Sand, April 1987"

Typical landfill costs are as follows:

CPA verbal quote	$\$20/m^3$
City of Calgary landfill	$\$26/m^3$
Independent landfill (ref. study)	$\$23.70/m^3$

Considering the large volumes involved and the clean nature of the sands, $\$20/m^3$ is achievable. A rough cost build-up is as follows for a 100 000 m^3 site.

Site acquisition and permitting	\$ 50 K
Site geology and hydrology	50 K
Prestripping 40 000 m^3	140 K
Ditching and Draining	100 K
Clay liner burrow pit and placement	400 K
Observation wells (8) @ \$25 K	400 K
Lift placement D-8 6 mo/yr for 10 yr	728 K
Well monitoring cost \$25 K/yr for 30 yr	750 K
Water treatment cost	200 K
Clay cap 3 000 m^3 @ $\$10/m^3$	30 K
Soil placement 10 000 m^3 @ $\$10/m^3$	100 K
Grading and Trimming 10 yrs	150 K
Reporting \$10 K/yr	100 K
TOTAL	\$2 998 K

The present value of this "Cradle to Grave" landfill cost is likely about $20/m^3$.

1.3 UTILITY AND OFFSITE SUPPORT REQUIREMENTS

The two STS-1000 units would require hot water to be heated from 4°C to about 77°C. The volume of each STS-1000 is 204 m^3 and will process 120 m^3 of solids daily along with 18 m^3 of water and 18 m^3 of hydrocarbon. A circulating hot water load would likely be required to keep the solids content low enough to separate. ASTCO submission shows a simple heat calculation of 440 kW per unit. A packaged boiler (quoted by H.F. Clark) would supply the heat (1.47 MW) and electric power to operate about 373 kW of electric motors. The boiler would be a Cleaver Brooks, 112 kW, 54 400 kg/d of steam unit capable of delivering 1.4 MW. It would be mounted in an enclosed semi-trailer along with a shell and tube heat exchanger capable of heating 102 m^3/h salty or muddy water. Steam flow control values would produce 82°C water with a T of 17°C. The unit would have a self contained 50 kW diesel generator. If the sites have electric power available, they would eliminate the power cost (about $41 000 per year). Otherwise, the plant would be set up to be self sufficient at each site.

1.4 OTHER OSBL SUPPORT REQUIREMENTS

Along with the operation of the plant, laboratory testing of the feed, product and solid tailings should be done every 4 hours. The cost of testing would be as follows as quoted by AGAT Laboratories.

Feed	$24
Product	$46
Tailings (small quantities of hydrocarbons)	$20
	$90/set.

Local trucking companies would provide haulage to the site from ecology pits and from the site to the landfill. A steam cleaning pad should be provided at each site by the operators to allow cleanup of mobile equipment.

Residual water would have to be disposed of in the batteries disposal well. No cost has been allowed for this.

1.5 CAPITAL AND OPERATING COST ESTIMATES

The cost date was developed by soliciting telephone prices for all components of the project. The respondents were as follows:

- Premay Equipment Ltd. 279-9775
  Moving equipment & pilot cans

- Husky, Lloydminster
  Trucking, F.E.L.'s and vacuum trucks

- ESSO Resources Canada Ltd. (Cold Lake)
  Trucking, F.E.L.'s and vacuum trucks

- AGAT Laboratories 291-2428
  Testing

- C&V Portable Accommodations Ltd. 279-7451
  Trailer Rentals

- Husky Bulk Sales — 234-8954
  Diesel Fuel Pricing

- R. Angus Alberta Ltd. — 275-3340
  (2) Cat 936, 101 kW 2.1 m^3 F.E.L.'s

- GENEREX, Edmonton — 483-0382
  Steam ticketed personnel

- H.F. Clark Ltd. — 255-0186
  Boiler & Diesel Generator

- CEC PAPKI — 262-5576
  Tanks & Pumps

Cost Estimate:

Capital Cost

(2) STS 1000 Units at $600 K each for 2 units	$ 1 200 K
(2) Premay compatible undercarriages	28 K
Extra controls and heating coils	100 K
112 kW packaged boiler	$ 125 K
	$ 1 453 K
Annual Cost (3 year straight line depreciation)	$ 484 K

Pre-Operation Cost

Soil Application and Approvals	$ 50 K
Mobilize (bids, fleet arrangements, etc.)	50 K
Program Outline - details with CPA members	50 K
	$ 150 K

Equipment Rentals (28 weeks)

Trailer, 3.1 m x 13.4 m (2 offices, phones, desks)	$ 14 K
(2) Trailers, 3.1 m x 12.2 m (lunchrooms, tools, lockers)	12 K
(2) 64 m^3 water tanks & 2 personal pumps	63 K
Diesel Generator 400 kW	45 K
14.5 tonne cherry picker & 13.7 m hi-boy	178 K
(2) 936 Cat, 101 kW 2.1 m^3 F.E.L.	69 K
Misc. hand tools	4 K
Porto-Pot Service	2 K
Potable Water	2 K
Trucking Cost (48 km average haul to site)	258 K
Trucking Cost (16 km average haul to landfill)	123 K
Disposal Well Piping	20 K
Landfill Cost ($20/$m^3$ - confirmed by CPA)	672 K
	$1 462 K

Moving Cost (6 Moves)

All loads hauled by rented semi	$ 0 K
Site preparation	30 K
Site clean-up	45 K
Electrical hookups $3 000/site	18 K
Premay - STS 1000 Moving costs (initial)	11 K
5 added moves	45 K
	$ 149 K

Operating Cost

F.E.L's operators @ $28/h (all up) 6 720 hours	$ 188 K
Site Manager (38 weeks)	133 K
Logistics Engineer (28 wks @ $45/h)	51 K
Cherry Picker Operators (incl. in truck rental)	0 K
Mechanic (28 weeks @ $35/h)	40 K

(3) STS Operators @ $25/h	$ 84 K
(3) Boiler Operators (Generex $33/h)	111 K
Living Allowance $75/d, (2 226 M.D.)	167 K
Diesel, F.E.L.'s 11 L/h (6 720 h) @ $0.347/L	26 K
FEL service costs ($4.50/h)	30 K
Diesel, boiler 225 L/h (3 360 h) @ $0.297/L	225 K
Diesel, cherry picker	10 K
Misc. tank & pump service costs	25 K
Laboratory Testing (6 samples/day) @ $90/set	76 K
Travel & Expenses $2 000/week	56 K
(4) 3/4 tonne trucks, equipped ($800/mo)	23 K
Vehicle Service, repair, fuel	12 K
Electric power, 373 kW @ 3.25/kW	41 K
Phone & LD calls	15 K
STS 1000 Fuel (included in boiler)	0 K
STS Unit Maintenance Cost (4% of $1.2 MM)	48 K
	$1 361 K

Cost Summary

The following is the cradle-to-grave cost:

Capital Cost (3 year write-down)	$ 484 K
Pre-operation Cost	150 K
Equipment Rentals	1 462 K
Moving Cost	149 K
Operating Cost	1 361 K
SUBTOTAL	$3 606 K
CONTINGENCY	not req'd
TOTAL ANNUAL DISPOSAL COST	$3 606 K

Based on a single season production of 10 m^3/h; 33 600 m^3 of oily solids could be disposed of annually by (2) STS-1000 hot water processors operating 28 weeks per year. The cost per m^3 of oily solids processed would be about $107.32 for the first three years. Thereafter, once the capital is paid out, the cost would be $92.92/m^3$.

2 FLUID BED COMBUSTORS

Pacific Environment Systems Inc. has formed a joint venture with Energy Products of Idaho and JWP Energy and Environment Inc. to design and build a fluid bed combustor for oily solids disposal. They presented generic process information in the form of their proposed $11.5 MM, 2 tph tire burning plant for TROCHU, which is somewhat different than the $3.75 MM, 13 tph oily sand combustor. They did, however, prepare an operating cost breakdown and an outline of testing required to design a plant. They did not respond to our request for information claiming detailed process and equipment information is proprietary.

2.1 PROCESS AND MECHANICAL SYSTEM DESCRIPTION

The earlier information suggested that the solids would be fed from a hopper to a transfer conveyor into a retort type fluid bed combustor where the hydrocarbon would be burned at 1038°C. Fly ash would be cycloned to remove dust down to 0,092 g/m^3. The stack gas would yield low NO_x, CO and hydrocarbon burnout at low excess air rates. SO_2 emissions could be controlled with limestone addition. The TROCHU combustor consists of a multichamber combustor with a travelling grate and auger ash discharge for tires. The stack gas cleanup system is extensive. Although it is an example of their work, it is not applicable to oily solids cleanup. Instead of limestone addition, they now propose to add 23 - 27 kg/h of caustic (on a 100% concentration basis).

The pilot unit is likely more representative of the expected commercial plant and more clearly described in Appendix 'E' Technology Master File, under Thermal Process. The vessel consists of a refractory lined combustion chamber, with ducting to a scrubber (probably a venturi type wet scrubber would be required). A gas fired preheater supplies hot fluidizing air to a manifold which distributes to the fluidizing bed through nozzles. Overfire air ports supply additional air to ensure complete hydrocarbon burnout.

The feed to the combustor must contain over 15% oil (minimum 5 815 kJ/kg) to sustain combustion, otherwise supplementary fuel would be added in the form of diesel or natural gas.

2.2 RESIDUAL DISPOSAL

The burned solids would be stocked out into a pile, loaded into trucks and hauled to a landfill, described in more detail in Section V 1-2.

2.3 UTILITY AND OFFSITE REQUIREMENTS

The utility requirement consists of 198 kW for fans, conveyors, pumps and augers (not sized). A 27 kg/h of 100% caustic system would feed the wet scrubber and a thickener would be required to settle out treated water. Dow Chemical supply 50% caustic from Saskatchewan. A sludge disposal system would dewater thickener underflow. Make-up water would be about 17 m^3/h. Some treated water would be disposed of in the site disposal well.

2.4 OTHER OSBL SUPPORT REQUIREMENTS

Along with the operation of the plant, the site must have a caustic storage tank and truck unloading system. The scrubber would likely use less than 50% strength caustic so a dilution system would be required.

The feed must be blended to avoid large swings in product and air quality, so a preorganized pickup schedule complemented by a blending area must be established in front of the plant.

A laboratory testing program would be required for feed and products and the stack gases would be sampled and tested quarterly. The feed and product would be sampled every 4 hours at a cost of $70/set.

Local trucking companies would provide haulage to the site from ecology pits and from the site to the landfill. A steam cleaning pad should be provided at each site by the operator to clean equipment.

2.5 CAPITAL AND OPERATING COST ESTIMATE

The information provided by Pacific Environment System Inc. was based on their proposed rubber tire burning plant at TROCHU, and as such was inaccurate and incomplete. The figures do, however, indicate that their preliminary cost of $35/$m^3$ (U.S.$) was low. They were not willing to develop any further costs until a test program is completed. Based on their preliminary information, the following cost analysis was developed. Equipment rental costs were as per Section 1.5.

Capital Cost

Provided without description or detail - $3.75 MM U.S.	
Annual Cost (3 year straight line depreciation)	$ 1 471 K

Pre-operation Cost

Permits & Licenses	$ 100 K
Coordination of Solids Delivery	50 K
	$ 150 K

Equipment Rentals (50 weeks/yr)

Trailer, 3.1 m x 13.4 m (2 offices, phones, desks)	$ 24 K
Maintenance equipment supplied at site by operator	0 K
(2) 936 Cat. 101 kW 2.1 m^3 F.E.L.	136 K
Misc. hand tools	8 K
Trucking Cost (97 km average to site, 3 trips/8 hours)	640 K
Trucking Cost (16 km average to landfill)	218 K
Landfill Cost ($20/$m^3$ - confirmed by CPA)	1 200 K
	$ 2 226 K

Operating Cost

(2) F.E.L.'s operations @ $28/h 8,000 h/yr	$ 448 K
Site Manager	150 K
Logistics Engineer	80 K
(4) Plant Operations @ $25/h (all up)	219 K
(4) Maintenance Personnel @ $28/h (all up)	245 K
Diesel, F.E.L.'s 11 L/h @ 0.347/L	67 K
F.E.L. Service Cost ($4.50/h)	79 K
Misc. Tools Etc.	8 K
(4) 3.4 tonne trucks, equipped	$ 39 K

Vehicle Service, repair, fuel	$ 24 K
Fuel - min. 5 815 kJ/kg (equivalent 11.9% bitumen) supplement 1 163 kJ/kg (13 tph) = 4.2 MW using natural gas at $\$70.43/10^3m^3$ operating 6 000 h/yr	215 K
Power - 321 kW @ $.0325/kW	63 K
Caustic 27.2 kg/h, 100%; Dow Chem Supply 50%, 328 000 kg/yr @ $0.515/kg	169 K
Caustic trucking (16) x $2 500/load	40 K
Laboratory sampling 4 hour basis	105 K
Stack Sampling & Testing hour (quarterly)	20 K
Plant Maintenance 4% of supply	175 K
	$ 2 146 K

Cost Summary

The following is the cradle-to-grave cost:

Capital Cost (3 year write down)	$ 1 471 K
Preliminary Cost	150 K
Equipment Rentals	2 226 K
Operating Cost	2 146 K
Contingency - Suggest 20% of Capital due to lack of scope definition	294 K
TOTAL ANNUAL DISPOSAL COST	$6 287 K

Based on the annual production of 10 m^3/h; 60 000 m^3 of oily solids would be disposed of. The all-up cost of disposing of a cubic meter of oily solids by the fluid bed combustion method would be $104.78 for the first 3 years. Thereafter, once the capital has been paid out, the costs would be $\$80.27/m^3$.

3 PRODUCED SAND REPLACEMENT/RE-INJECTION

Halliburton offered an hydraulic fracturing technology for deep well disposal of oily solids, slop oils and salt water. Hydraulic fracturing has been practiced for the past 38 years representing a well proven technology to a new application. Halliburton has already worked with several heavy oil operators to reinject oily sands and wastes. The technology is not new, it is offered on a day to day basis without licensing fee, and is applied in a slightly different manner for oily solids disposal.

Fracturing is a method of applying hydraulic pressures (typical pressures required of the Lloydminster area) to fluids and solids slurry causing vertical cracks to open in a formation, with the slurry being deposited in the cracks. When the fracture is completed, the slurry is compressed (dewatered) and the fluids released to the surrounding formation. Fracturing is applied to old abandoned wells completed similarly to those in the area. No special completion or new wells are required. The well specification preferred for this technology should have the following characteristics as described in the next section.

3.1 DISPOSAL WELL REQUIREMENTS

1. A site with a large lease area is preferred so that storage tanks can be spotted and large equipment can be driven onto and off the site with relative ease.

2. A well with a 7" casing is preferred. It is important that there is a good cement bond to the casing above and below the proposed disposal zone.

3. The disposal zone should have a good competent shale zone of at least 2 metres in thickness both above and below it to help prevent the disposal slurry from breaking out of the zone.

4. A 20.7 MPa wellhead is required.

5. The well must have 76 mm or 89 mm workstring with a packer just above the disposal zone.

6. The disposal zone should be perforated with a large charge casing gun at a minimum of 13 s/m (shots/meter).

7. The proposed project must be given government approval.

8. The disposal zone should be deep enough so that even if the disposal frac were to break out of the zone there would be little chance of it coming in contact with a potable water source.

Formation Behaviour

The slurry being injected would have a higher permeability than the reservoir itself. In the Lloydminster area, the fractures are generally vertical following the rock joints (butt and cleat) of least resistance rather than the bedding planes. Each fracture will create new triaxial stresses so that the next fracture will be different. Subfractures will also develop along the main fracture planes and eventually the bedding plane may also fracture. Figure 5.1 demonstrates a typical fracture system from a well base.

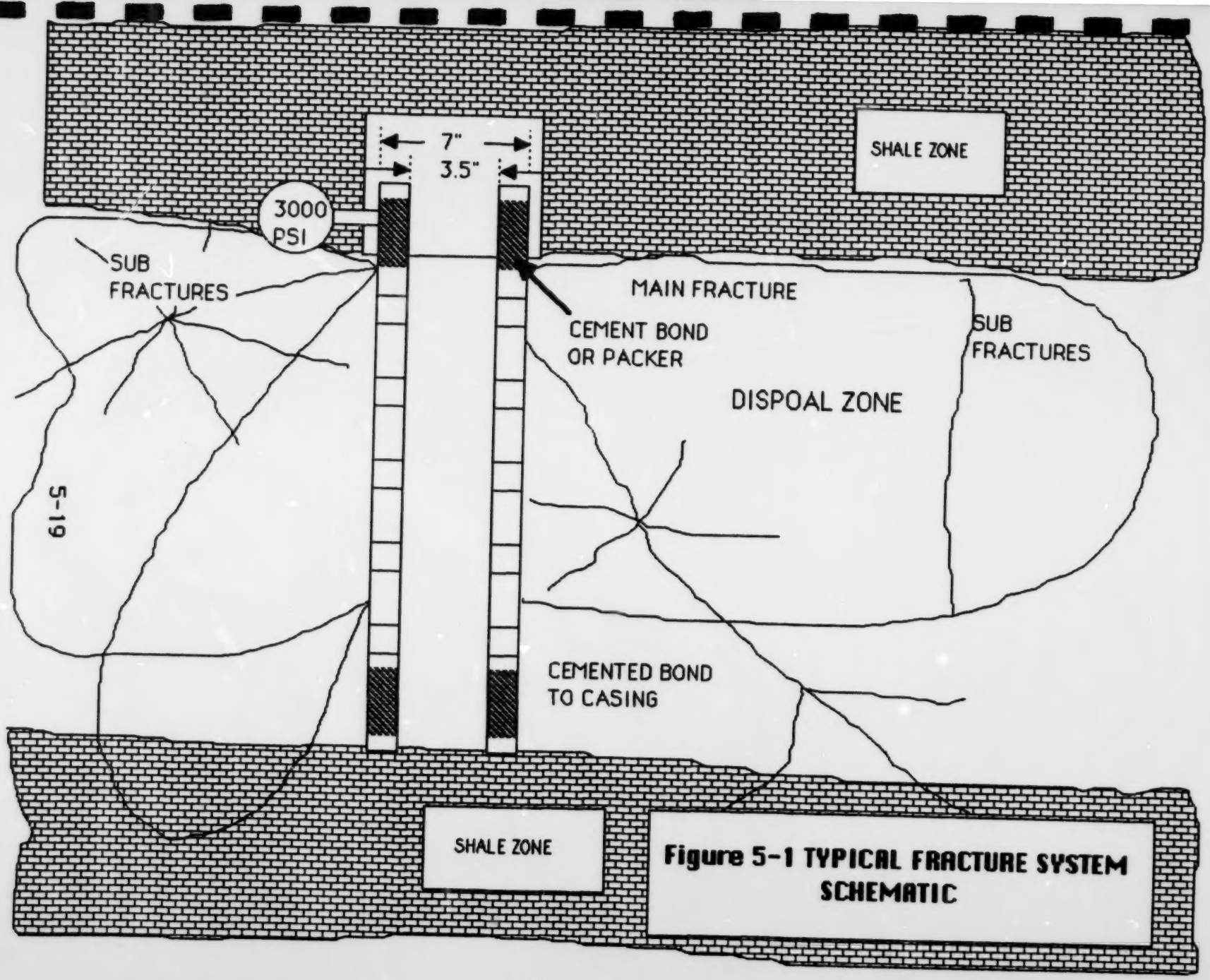


Figure 5-1 TYPICAL FRACTURE SYSTEM SCHEMATIC

3.2 SLURRY CHARACTERIZATION

The prepared fracturing slurry should have a solids to liquid ratio of 1,400 kg of solids per cubic meter of fluid. The fluid can be slop oil, salt water or fresh water and must be heated sufficiently to be pumpable by centrifugal pumps. The solids are limited in top size to 10 mesh by the positive displacement injection pumps. However, the slurry preparation unit which is confidential at this time, has been reviewed by Monenco and found to be a practical separation method for coarse solids. These solids would be washed clean of oil and be available for reuse at well sites or for disposal. Other than in the Cold Lake area, these solids would not be of a significant quantity. At Cold Lake, Esso spread gravel at their well roads to keep the areas clean, then use the gravel for road surfacing.

3.3 SLURRY PUMP

The injection pumping unit is shown in the attached leaflet. The model 77 TF pumper is a diesel driven triplex positive displacement pump capable of delivering up to 41.4 MPa. Although this high pressure is not required, the unit is a standard manufacture and readily available for oilfield service (i.e. cost effective). The capacity for injection is up to 1 500 kg of solids per minute (about 50 m^3/h). In general, on single site applications, the limiting factors are the delivery of the solids and the availability of hot water and injection fluid. Mobilization, demobilization and infrastructure make small size hydrofracture operations too expensive.

3.4 SLURRY PREPARATION PLANT

The slurry preparation plant consists of a special proprietary Halliburton vessel which separates the coarse gravel

from the finer slurry. The vessel has been discussed with Monenco Consultants and Raymond Mineral Dressing Consultants and is fully functional. The coarse material from the vessel will be suitably washed (oil free) and can be used to reclaim the site.

Oily solids would be fed into the Haliburton slurry vessel with a 936 Caterpillar Front End Loader at about 50 m^3/h. Hot water (salty or otherwise) would be heated in an exchanger and fed into the slurry vessel to render the 50% by weight solids slurry pumpable. An oil field boiler (2.1 MW) would be mounted on a semi-trailer along with the exchanger and diesel electric set to provide site utilities. Local electricians would hook up electrical services and provide any electrical repairs at the site.

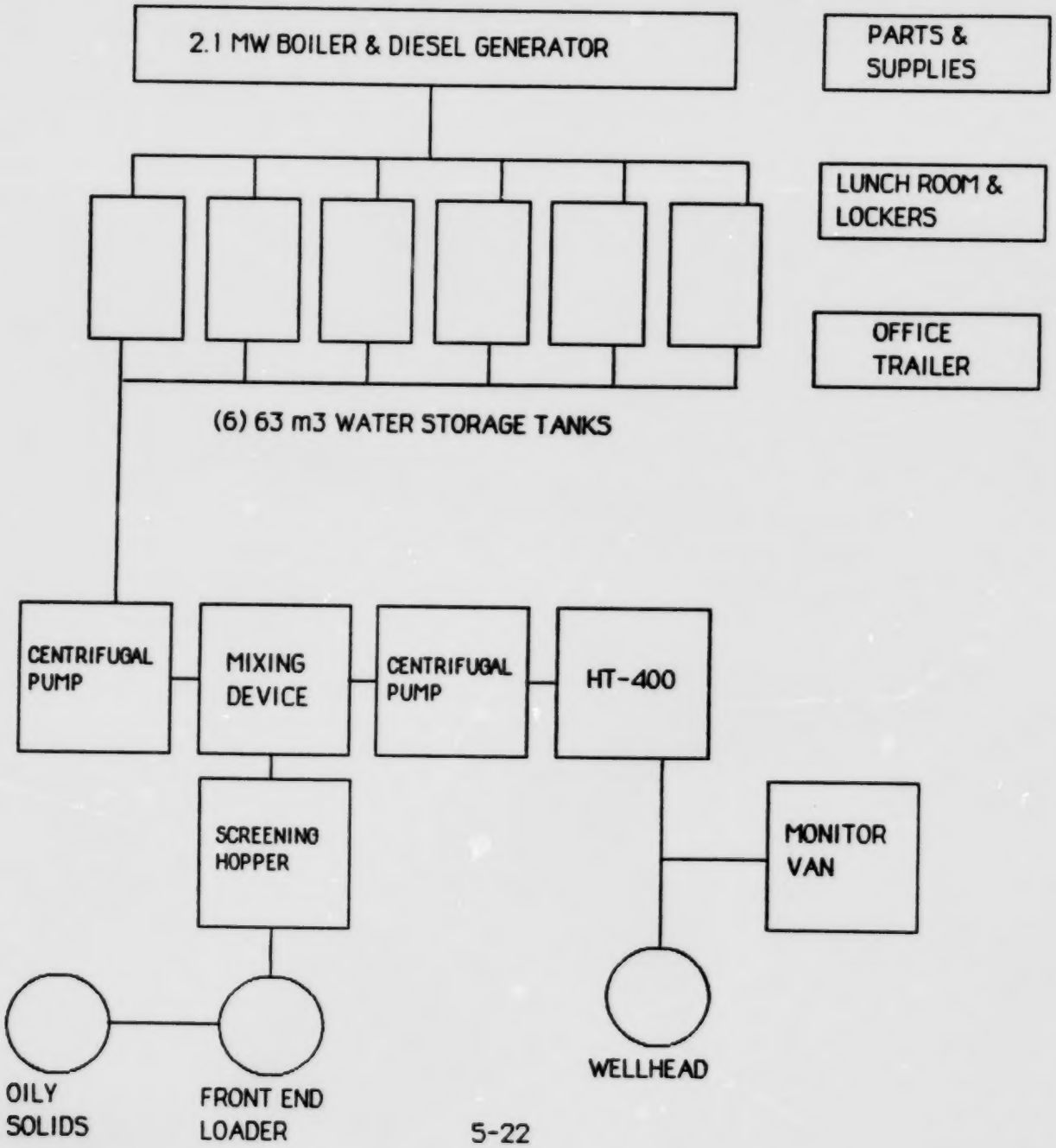
Hot water would be supplied from 300 m^3 of storage tanks required to sustain 8 hours each day of injection. Each location for re-injection should have 22.7 m^3/h of water available for filling the tanks.

3.5 PRODUCTION FACILITY DESCRIPTION

In order to sustain a low unit cost for reinjection of oily solids, a program should be organized by all heavy oil operators to utilize the special equipment required for the entire summer season. This would eliminate the high mobilize/demobilize cost of single injection program. Fifteen to twenty sites should be selected for injection, along with the necessary truck fleet, tanks, packaged oilfield boiler, crew and front end loaders hired to provide maximum injection capability for each day worked. Figure 5.2 shows a typical site layout. Working days would be 12 to 14 hours with about 8 hours of injection time and a planned injection rate of 350 m^3/d. Dedicated equipment and crews would increase efficiency and minimize the impact of relocations. A disposal schedule would allow cleanup for even small operations. Oily solids would be loaded from ecology pits by a front end loader into a fleet

FIGURE 5-2

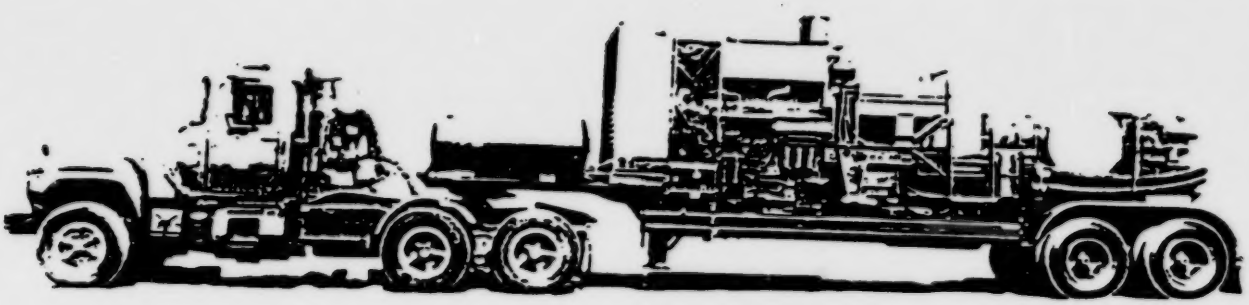
EQUIPMENT LAYOUT FLOW CHART (HALLIBURTON SERVICES)



HALLIBURTON SERVICES

FRACTURING TECHNICAL DATA

Model TF Pumping Unit



A recent product of Halliburton's continuing evaluation/design program for mobile pumping units is the Model TF for high pressure, high volume fracturing. Currently in production, the unit provides maximum pressure of 20,000 psi or maximum volume of 56 barrels per minute.

Primarily, this is a trailer-mounted Twin HT-400 pump unit with each pump powered by a V-12 turbocharged, intercooled diesel engine, together producing 1,400 BHP or 1,188 HHP. Power train is a 5-speed power shift transmission. Selection of five sizes of fluid ends in the HT-400 pump will depend on operating requirements in the area where a particular unit is based.

While this is the most efficient diesel-powered mobile pumping unit in operation that conforms to standard highway weight and size requirements, overall operating efficiency has not been sacrificed. The diesel engines are turbocharged and intercooled and fans are engaged and drawing power only when the engines require cooling.

The TF is designed to complement such Halliburton blending units as the 80 TRPS 50. A booster pump is mounted aboard the blender rather than the base pumping unit.

The power shift transmission can be shifted at full RPM. The torque multiplication effect of the converters offers the particular advantage that in case of a pressure surge caused by a ball-out during injection of Perfpac ball sealers, a quick power shift can forestall a pressure drop great enough to cause loss of the balls.

Ample pressure gauges and pressure limiting devices help make it possible for the operator to provide the precise control and safety needed for today's high pressure, high volume stimulation treatments.

of trucks. The truck loading FEL would schedule moves from site to site so that day light operation of the truck fleet would coincide with the injection operation. The loading FEL loader would work two shifts to ensure that moves could be completed and the injection fleet would not be held up.

Moves would be made about every 2 to 3 weeks (assuming 4,000 m^3 injected at each site). Local tractor trailers would be hired to move the tanks, boiler trailers, and hoppers. The Halliburton equipment would move immediately after injection is completed to prepare for the next well.

The boilers would be about 2.1 MW with an oversized heat exchanger so that low quality (high salt) water could be heated 24 hours per day. A diesel generator would be mounted on the same trailer as the diesel fired boilers to provide lighting for the site. Fuel tanks for the boiler, generator and vehicles would be used at the site. Local bulk stations would provide diesel to the fleet storage tanks.

A "cherry picker" (14.5 tonne) mounted on a tractor along with a Hi-boy would be available on the site for moving equipment and would be used to load during the moves.

Three trailers would be located at the site to be used as offices, lunch rooms, change rooms and lockers for tools storage. Repair and overhaul would be done largely by the Halliburton Fleet. Men would be housed in a nearby town, and a living allowance of $75/d has been provided to cover accommodation, meals and travel.

The manpower required to operate the fleet including the two FEL's, boiler, and site (excluding truckers) is as follows:

Manpower Requirement

	Persons
Site Manager	1
Logistics Coordinator	1
Boiler Operators (3rd Class Steam Tickets)	3
Cherry Picker Operators	2
FEL Operators (1 on site, 2 remote)	3
Haliburton crew	4
Mechanic	1
Total	15

Schedule

- 12 - 14 hours/day operating
- 7-8 hours/day injection
- 5 days/week
- boiler heating 24 hours/day
- 2 - 3 weeks/site
- 2 days to set up and move
- April 1 to October 10, 1991 (28 weeks)
- Min. 40 000 m^3 injected per season

3.6 COST ESTIMATE

The cost of the program was developed by soliciting telephone prices for all components of the project. The respondents were as follows:

- MN Trucks & Crane Service Ltd. 273-0990
  14.5 tonne Cherry Picker, c/w 13.7 m Hi-boy

- Husky, Lloydminster
  Trucking, F.E.L.'s and vacuum trucks

- CEC PAPKI 262-5576
  Tanks & Pumps

- R. Angus Alberta Ltd. 275-3340
  (2) Cat 936, 101 kW 2.1 m^3 F.E.L.'s

- Challenger Rentals, Nisku 955-7324
  Tanks & Pumps

- H.F. Clark Ltd. 255-0186
  Boiler & Diesel Generator

- C&V Portable Accommodations Ltd. 279-7451
  Trailer Rentals

- GENEREX, Edmonton 483-0382
  Personnel (3rd class steam ticket holders)

- Halliburton Services Ltd. 269-6141
  Reinjection Equipment & Well Service

- Husky Bulk Sales 234-8954
  Diesel Fuel Pricing

In addition to the Halliburton costs quoted, well preparation costs could be as follows:

Service rig - 2 days @ $170/h
New Tubulars, etc. - $15 000
Full Bore Production Packer - $7 000
Logging $2 000/well
34.5 MPa well head $2 000 ($500/d)

Completion - 2 days service rig

- Squeeze off zone - $4,000
- Use $8 000/well to abandon

Cost Estimate:

Pre-operation Costs

Government Reinjection Approvals	$ 50 K
Mobilization (bids, fleet arrangements, etc.)	50 K
Program Outline - details with CPA members	50 K
SUBTOTAL	$ 150 K

Equipment Rentals (28 weeks)

Trailer, 3.1 m x 13.4 m (2 offices, phones, desks)	$ 14 K
(2) Trailers, 3.1 m x 12.2 m (lunchrooms, tools, lockers)	12 K
(6) 63.6 m^3 water tanks & 2 diesel pumps	189 K
Packaged Boiler (2.1 MW) $12 K/month	72 K
Diesel Generator	45 K
14.5 tonne cherry picker & 13.7 m hi-boy	178 K
(2) 936 Cat, 101 kW 2.1 m^3 F.E.L.	69 K
Misc. hand tools	4 K
Porto-Pot Service	2 K
Potable Water	2 K
Trucking Cost (32 km average haul) 6 trips/8 hours	213 K
Halliburton Injection Cost $12 000/d	1 680 K
Temperature Logger - 12 sites	24 K
Halliburton Slurry Tank & Slurry Pumps ($600/d)	84 K
Well heads (12)	24 K
Halliburton Well Preparation (12 wells) @ 2 days/well	49 K
Packers (12 wells) and new tubulars	264 K
Completions (12) @ $8 000	96 K
SUBTOTAL	$3 021 K

Moving Cost (12 moves)

10 loads @ $850/d (tractor)	$ 102 K
Site preparation	60 K
Site clean-up, well abandonment	90 K
Electrical hookups $3 000/site	36 K
SUBTOTAL	$ 288 K

Operating Cost

F.E.L's operators @ $28/h (all up) 5 040 hours	$ 141 K
Site Manager (38 weeks)	133 K
Logistics Coordinator (28 wks @ $45/h)	51 K
Cherry Picker Operators (incl. in truck rental)	0 K
Mechanic (28 weeks @ $35/h)	40 K
(3) Boiler Operators (Generex $33/h) 3 360 hours	111 K
Living Allowance $75/d, (2 548 M.D.)	191 K
Diesel, F.E.L.'s 11 L/hr (5 040 h) @ $0.347/L	20 K
FEL service costs ($4.50/h)	23 K
Diesel, boiler 350 L/h (3 360 h) @ $0.297/L	350 K
Diesel, cherry picker	10 K
Misc. tank & pump service costs	50 K
Travel & Expenses $2 000/wk	56 K
(6) 3/4 tonne trucks, equipped ($800/mo)	34 K
Vehicle Service, repair, fuel	18 K
Phone & LD calls	15 K
Halliburton Fuel 300 L/h, 13 h/d @ $0.297/L	162 K
SUBTOTAL	$1 405 K

Cost Summary

For 40 000 m^3 of solids reinjection and or equivalent quantity of fluids, the overall cost of a reinjection program is as follows:

Pre-operation	$ 150 K
Equipment Rentals	3 021 K
Moving Cost	288 K
Operating Cost	1 405 K
SUBTOTAL	$ 4 864 K
CONTINGENCY - 12%	584 K
TOTAL COST	$ 5 448 K

One of the advantages of this type of program is that it can be discontinued after one season if it is not successful, and additionally, slack time due to shortage of water, fuel or slurrying liquid supplies is conceivable, such as experienced before by Halliburton. It is these consideration that a 12% contingency is applied above.

The cost per cubic meter of oily solids disposed of for a 40 000 m^3 injection season is then $136.20.

4 ESSO ROAD APPLICATION

Esso Resources Canada Limited in conjunction with their local municipality, have developed a road surfacing technique which results in an acceptable surface. The technique may not satisfy those requirements in the future, however, it is a current practice. The cost to Esso Resources, excluding future reclamation, is quoted as $70/$m^3$ of oily solids which is very low compared to the cost of actual paving of a county road. A typical municipal road surfacing program would be $60 000/km of which about $18 000/km is provided by Esso Resources Canada Limited in the form of material supply and application. The actual road bed preparation costs are not included

since the site roads must be built in any case. Although the Esso costs appear low, they are correct and have been examined in detail. They make an effective use of resources and one must keep in mind that road surfacing is just improving on what is already required.

4.1 PROCESS AND MECHANICAL SYSTEM DESCRIPTION

The following section describes Esso's road surfacing technique.

Materials

The oily sand generated at Cold Lake comes from two sources: as a byproduct of bitumen production from the Clearwater reservoir, and from surface lease cleanup activity. By far the majority of the oily sand originating from the reservoir is characterized as a liquid sludge consisting of bitumen, fine sand and water and is found in plant vessels and tank bottoms. It is moved to the sand pits during the annual plant turnarounds. Oily sand generated by surface lease cleanup activity is comprised of bitumen contaminated solids (coarse gravel, fine gravel, sand and clay). These solids are placed in the sand pits during on-going operations.

A typical drained analysis of the oily sand found in the sand pits is 13% bitumen, 7% water and 80% solids by weight.

Sampling of the sand pit fluids has found chlorides typically range from 2 000 - 9 000 mg/L.

Esso Resources' Cold Lake operation generates about 16 m^3/d (6 000 m^3 per year) of oily sand byproduct. Oily sand production relative to total fluid production is negligible; it is estimated to be less than 0.02% by volume. The total volume of sand

produced becomes significant because of the site's overall total fluids production of 31 000 m^3/day of water and 14 500 m^3/d of bitumen (1988 figures), and as such must be dealt with. Esso manage about 40 km of road within their leases and must maintain these roads regardless if they are surfaced or not. Surfacing provides effective use of the site materials.

Preparation & Application Methods

Sand Pit Operations - The job starts by controlling what is 'donated' into the sand pits. It requires a site wide integrated waste management strategy and control to ensure that materials end up in the right place. Esso Resources' Cold Lake operation has found through experience the best way to ensure that only produced fluids and oily sand byproducts are added to the pit's contents was to assign ownership of each pit to a dedicated individual. The pit is secured with a locking gate. A manifest of all pit material is required and kept on record. Ecology pits must have inflow controlled, monitored and managed so that road surfaces can be made the best possible. Organic materials and soils should be avoided.

Initially, all of the free fluids (bitumen and water) contained in the sand pit must be drained off and pumped out. This increases viscosity, decreases salt content and helps adhesion of the oily sand byproduct. Steam coils, hot water circulation and separate compartments connected by drainage weirs within the pits are used to maximize free fluids extraction. Fluid removal is done with a permanent pump installation in the pit, and vacuum trucks. The fluids are recycled back to the plants. Drainage activity should be started prior to, and maintained during the removal of

oily sand from the pit. It is essential to dry the material as much as possible since road surfacing should be done at less than 5% by weight moisture.

The oily sand left after free liquid removal is tested for chlorides and pH. The maximum acceptable chlorides level is 2 000 ppm but averages about 500 ppm. PH ranges between 7 and 9.

Activities up to this point are done by Esso Resources employees to ensure control of the pit contents. After the oily sand material in the pit is drained and ready for road mixture application, a contracted crew is mobilized to remove the oily sand byproduct from the pit. Sands are blended with gravel in the pit using a Cat 975 F.E.L. Local truckers are contracted as required. Lost time and down time are minimized.

The crew must complete a site-wide contractor's orientation course and 'tailgate' safety meetings focusing on the job at hand, prior to starting work and weekly thereafter. Subjects covered include the job objectives and expectations, the safety concerns related to the job, Workplace Hazardous Materials Information Systems (WHMIS), and Transportation of Dangerous Goods (TDG) compliance considerations.

Gravel is usually included as a road surface material; it is premixed in the sand pit by dumping gravel into the pit and mixing it with a front end loader. The desired composition varies (depending on the road bed and pit contents), but usually is close to a 1:1 mixture by volume of oily sand to gravel.

Using a front end loader, the oily sand is lifted out of the pits into trucks and hauled to where it is placed on the roads, ensuring the trucks don't drip enroute.

Road Surfacing - Roads crews are experienced contract personnel; they are usually mobilized at the same time as the sand pit cleanup operations, with a similar orientation.

Windrows on the road surface are developed by blading loose material to the centre of the road surface and adding gravel. It is desirable to avoid including topsoil, weed clumps and hard clay. At times, the road surface will be ripped up by the grader blades and pulverized. If this occurs, it is recommended to avoid disturbing the clay road base and to remove large rocks which may have appeared. Parallel windrows should be laid out so that a trench in the road centre is formed.

When material arrives from the sand pit, it is laid in the trench between the windrows. If bitumen is applied, this is done by using a vacuum truck with spreader bars to minimize splashing. Application rates will depend on the specifics of the road bed and the oily sand/gravel mixture. A typical shift is 7 a.m. to 3 p.m., deliver material to the road; 3 p.m. to 7 p.m., spread and pack the material.

After application, the oily sand mixture is graded, mixed and dried. The amount of drying depends on the initial water content of the pit material and the weather. Grading and mixing should take place directly behind the unloading truck. The grader blade is set flat and low to the road surface; the grader operator will grade the windrows in towards each other until both have been combined into one large windrow. Then the windrow is rolled across the road a number of times to ensure a consistent mix and remove moisture down to at least 5%. Drying the mixture while developing the proper consistency requires experience from the grader operator and warm, dry weather.

If the mixture becomes very wet (i.e. if it rains), the rolling and mixing may take a number of days. When this occurs, precautions to prevent runoff at sensitive areas are taken. Windrows at ponds are doubled, and also placed at the high side of elevated curves to provide runoff control in the event of rain. This must be done before leaving the worksite overnight. The windrow placement is detailed in Figures 5-3 and 5-4. Runoff accumulation may need to be collected with a vacuum truck. Negligible or no 'sheen' on the surface or standing water along ditch lines, and no vegetation stress from chlorides, has been observed while using these precautions.

When the proper consistency is achieved, the mixture is laid out on the road bed as soon as possible. The mixture is windrowed to one side of the road surface by the grader, and then the windrow material is pushed across the road in small lifts (maximum 50 cm high) to the road surface elevation. Cat 14 or Champion 740 or 760 graders with rippers are used.

Immediately following the grader should be a wobbly wheel packer. Proper packing at this stage is critical. If local traffic can be controlled, it is desirable to let the traffic through to help pack the mixture. For best results, packing should be continuous for several days in between lifts, and continue for several days after the last lift. Using a 'sheep's foot' packer will ensure sufficient compaction at the road edges.

A good and simple test for proper compaction is to try to grind the heel of a boot into the road surface. If no indent is made then there is sufficient compaction.

Final compaction is done with a grader 'tight blading' (the blade is close to horizontal to the road surface causing surface compression) followed closely behind with a smooth drum

Figure 5-3 Windrow Placement At Ponds

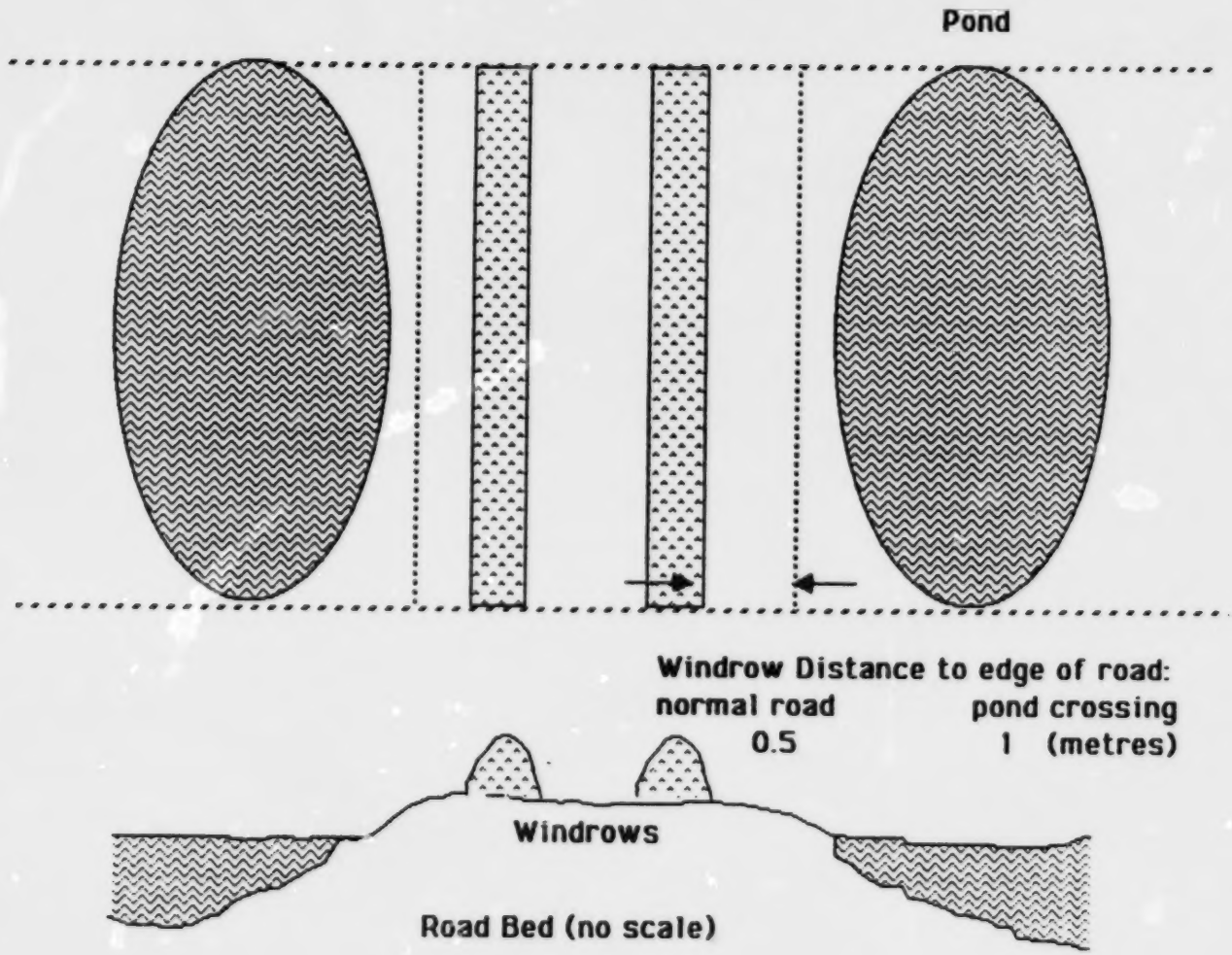
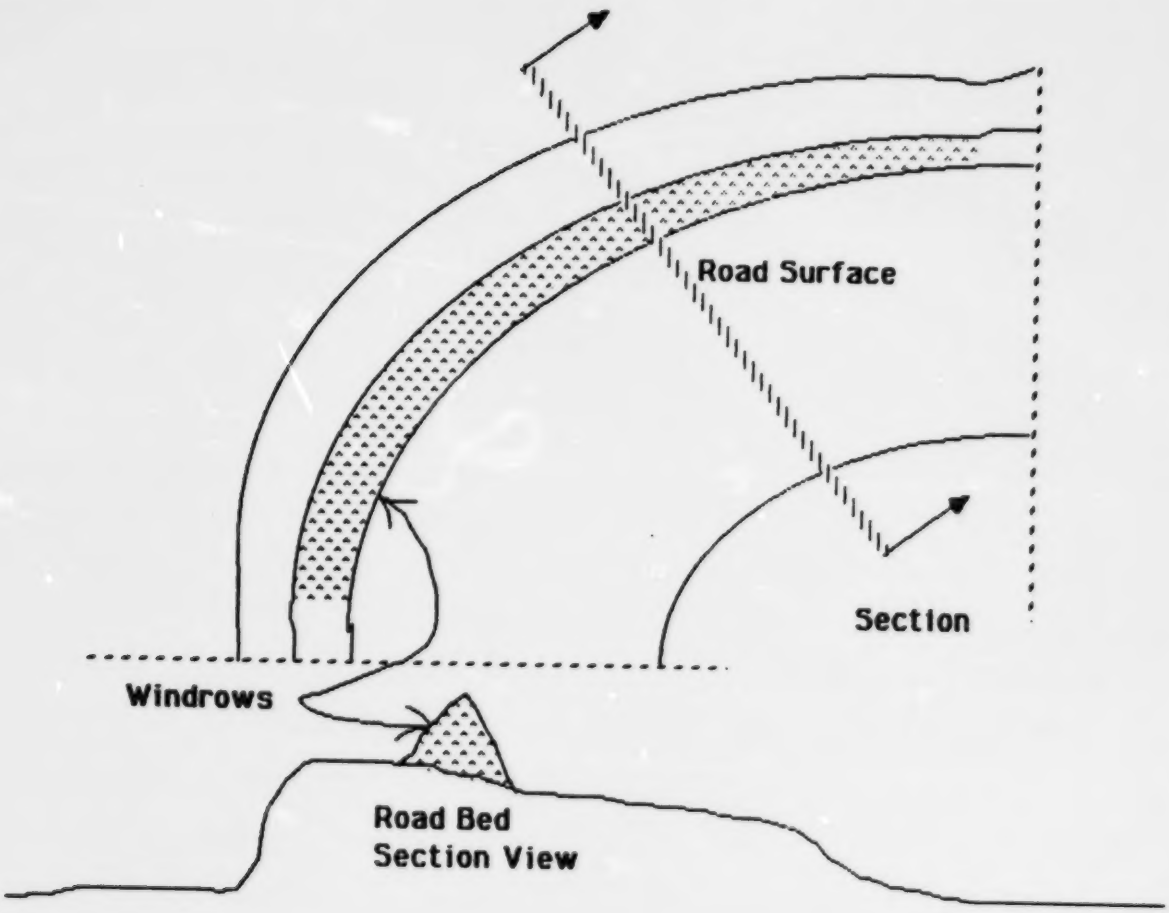


Figure 5-4 Windrow Placement On Banked Road Surfaces



Windrow placement on high side of curve
-Leachate runoff absorded by road surface
-No large accumulation of water on low side of road

vibrating packer. The grader operator should put new blades on for this step. The smooth drum vibrating packers will actually bring an oily film to the surface which seals the cap.

Virgin roads are handled in a similar manner. A few weeks before surfacing, the ditches are "pulled" with 2-3 graders to remove grass, etc. The surface is ripped. Materials are delivered to the windows from ecology pits and the graders work the windows to dry the solids. When the material reaches the right consistency, it is windrowed off to one side. Lifts are put down in 50 mm compacted layers, one lane at a time. Road widths range between 9 and 32 meters. Wobble wheel packers follow right behind the graders. Turning in the ditches is avoided so as not to damage the area. Thin lifts are then put down and compacted with a vibrating smooth roll packer to about 76 mm.

The next year, soft spots are removed. The "dust cap" is roto-tilled and built up. The cap and pack procedure produces a surface which is almost asphalt quality. Repairs at Esso require only 2 to 3 days per year.

Guidelines

Road surfacing with oily sand has been administered by Esso Resources as a project. As such, a number of guidelines have been developed and follow below. A summary of what may go wrong during road surface work is given in Table 5-I.

Road Surface Quality - The finished product should have a smooth, well compacted surface that will handle large volumes of traffic and loads up to 35 tonnes axle weight in all weather conditions. The road surface should be raised above the ditch line with a slight crown in the middle. Ditch lines must be free of

TABLE 5-1

Oily Sand Road Surfacing Troubleshooting Chart

Component	Contributing Factor	Indicators
Road Surface Mixture Quality	Good Mixture	does not stick to tires or boots no runoff or leaching to landscape even, dry, consistent road surface
	Too much bitumen	will puddle will flow into ditch appears slick and shiny will stock to surface of boots and tires does not roll off grader blades evenly or smoothly grader and mixers loose traction vehicles will deform road surface
	Not enough oil (mixture too dry)	coloration of road surface mixture not consistent mixture not a dark color (brown, not black) patches of dry dusty sand or gravel
	Mixture too damp	no cohesion of mixture leaching takes place road surface will break down readily mixture is dark in color
Compaction	Good compaction	road surface hard, packed tightly consistent color no loose material or free standing liquid no indents left in road after vehicle traffic passage should not be able to grind boot heel into surface
	Insufficient compaction	road edges break after a short period of use heavy vehicles deform road surface outwards loose mixture on road surface ripples develop on road surface

debris and follow the landscape contours. The road is to be built in such a manner that it will last for years with a minimum of maintenance.

Controls - Security for the sand pits is necessary; the materials being deposited into the pits must be monitored and controlled to ensure that only oily sand in conjunction with reservoir fluids is deposited. Volumes of material entering and leaving the pits must be recorded. Periodic tests of pit liquids for chloride content must be taken and kept to ensure the roads may be reclaimed.

Environmental Considerations - Complete control of the road surfacing mixture is a must while transporting and laying out on the road. Precautions are taken to ensure no splashing or runoff into ditches occurs. Locations where the roadway runs by ponds and/or streams will have windrows on both sides of the road.

Reclamation considerations and planning should be included for road surfacing on non-permanent roads. Chloride application rates are kept well below a maximum landspreading guideline of 450 kg of chlorides per hectare.

Hot sand is used for winter ice conditions as opposed to salt.

Safety - The project must comply with all federal, provincial and corporate regulations and guidelines. Activities must be monitored to ensure no downgrading incidents or near miss situations occur. The contractor's crew will participate in district orientation and safety programs, including weekly tailgate safety meetings chaired by the contractor. It is desirable to encourage the contractor to administer their own safety programs.

All equipment is safety checked before work is started and every two weeks thereafter.

The road surface itself, if prepared in this manner is not slippery.

Supervision - A major contributing factor to the road surfacing success is close supervision of all activities. This ensures that good quality roads with minimal environmental disturbance become the expected norm. It is desirable to have supervisory personnel with a good understanding of the job objectives and be familiar with the equipment and techniques being used. Esso Resources' experience has shown savings realized by good job supervision more than covers supervisory expenses. Equipment which is hired is fully utilized. Esso's manager judges the local weather and works the equipment accordingly. Contract equipment is available in the area on a short notice basis.

Continuous Improvement - It is expected that improvements to reduce costs and improve the road surface effectiveness are possible and will be forthcoming year to year. Some examples of innovations and improvements to the technology include:

- use of commercial 'cold mix' purchased from an asphalt company to repair potholes in the road surface;
- increasing gravel to oily sand ratios;
- premixing gravel with oily sand in the sand pits;
- using hot sand (rather than salt) on road surfaces in the winter.

Cost, Scheduling and Job Management Considerations

A strategy for road improvement over a 15 year period at Esso Resources' Cold Lake leases has been developed. The strategy, while subject to change due to oily sand byproduct availability and the business climate, has allowed road surface improvement to be done in an effective manner, and is consistent with a development plan. Short term benefits of the strategy-in-place include efficient deployment of equipment and person resources, and a steady work load for contracted crews.

Oily sand road surfacing costs have averaged between $10 000/km and $18 600/km (based on the period 1986 - 1989). Ecology pit equipment costs for pit cleanup average $2.50/$m^3$, not including the material costs of gravel addition. Note that the gravel would have to be used on the roads in any case since road maintenance is required at the site. Including sand pit handling costs, oily sand byproduct usage costs about $70/$m^3$. This cost is directly attributable to the sand. Because of the excellent results, road maintenance costs have been reduced. The $70/$m^3$ does not reflect those savings.

Equipment and gravel costs are driven by economic factors, especially the level of activity in the area. Overall, costs have fluctuated very little year to year. Equipment rates were examined and found to be compatible with rates in other areas.

Activity to clean out the sand pits and place the material on the roads is tendered as two separate contracts in April. In the first half of May, a construction supervisor is hired to oversee both activities. All activity takes place on Esso Resources' leases and is supervised out of Esso Resources' Cold Lake District Maintenance office. Experienced operators, especially grader operators are a key consideration for the choice of contractors.

Road surfacing improvement activity starts in May and continues through to the end of September. Weather warm enough to dry out the road surface mixture for compaction is the determining factor. Compaction and water content are the keys to performance.

Future Technology

Esso Resources' efforts to improve oily sand road application technology focus on cost reduction, extending the road application weather window, improving road durability and reclamation.

An opportunity to do both cost reduction and extend the weather window is available. Controlling the road surface mixture preparation at the pit to an optimum content of water, bitumen and gravel, will make a 'cold mix' ready for immediate road application. The weather window for application may be extended to include May through mid-October when it isn't actively raining; eliminating a significant amount of the drying time now required (estimated to be 50% of the May-September season). This may be done via enhancements to the pit's fluid extraction processes, and the addition of a roof over the pit area to stop rain influx.

Understanding the cost-benefit relationship of road surface compaction and road surface longevity will be useful. Directionally it has been observed that the roads which had better compaction also have lasted longer, but there has not been a large enough sample size and experience with road lifetimes to define the optimum. There may be benefits from compaction qualification via core sampling.

Gravel addition is a significant cost factor. There is a need for a better technical basis for determining how much gravel is needed.

In the future some of the roads which may be upgraded may be eventually reclaimed. Expectations are based on limited experimental study and experience from similar applications. Roads which were 'oiled' in the 70's during Esso Resources' piloting days at Cold Lake have reclaimed naturally, after being ripped and seeded. The gravels must be spread so that trees can also grow. Secondary lease roads must be reclaimed in any case, so there is no differential cost associated with the fact that oily sands have been used in the road construction. If there is additional cost, it would be a small cost for monitoring (coring, testing, studies, etc.). This cost would not be more than $\$5/m^3$.

Conclusion

Ongoing investigation of cost effective as well as environmentally safe methods to use oily sand byproduct at Esso Resources' Cold Lake have resulted in the development of a technology to use oily sand as a road surfacing material. It has been shown that:

Use of the oily sand byproduct as a road surface material can result in a high quality, all weather, durable road surface capable of handling traffic exceeding 400 vehicles/day and loads up to 35 tonnes axle weight. The road surface is not an environmental hazard and reclaimable with existing technology.

The road surfacing methods use commonly available road building and maintenance equipment, and adapt techniques used for laying asphalt to achieve a road surface which approaches asphalt in appearance and performance closely.

Gravel addition to the oily sand is a key ingredient for road durability. The initial road surface, and the road surfacing mixture must be dry prior to surface compaction. Otherwise the

resultant road surface will break up. Proper road surface compaction is essential for road longevity. Compaction is a multistage process, using several packing techniques.

A key factor to achieving high quality road surfaces is having a clear vision of what your standards and expectations for the road surface will be, and communication of this to the people doing the road surfacing work. Close supervision and job quality control are essential.

Oily sand road surfacing operations can occur May through September, during dry weather. Control of moisture content in the road 'mix' will extend the time available for road application within this weather window, and will also lower road surfacing costs.

Esso Resources' current oily sand road surfacing costs are in the order of $14 000/km. Oily sand byproduct handling costs, including road surfacing, cost about $75/m^3.

4.2 RESIDUAL DISPOSAL

There are no residuals to be disposed of. At times, extra bitumen must be added to the mixture to achieve the desired consistency. The cost of the added bitumen is not accounted for in the Esso figures. A mixture of 1:1 oily sand to gravel is used for surfacing. No mention is made of the bitumen quantity in the mixture; however, it is about 6 - 8% which is similar to Alberta highway paving standards. A front end loader blends the oily sand and gravel until the paving aggregate has "the right look and feel" to it, which is not unlike conventional practice. At the 1:1 ratio and average ecology pit bitumen content of 13.5%, very little would be required.

4.3 UTILITIES AND OFFSITE SUPPORT REQUIREMENTS

The following lists contain the major pieces of equipment typically used during a season's operations:

Sand Pit

The following equipment is used to mix gravel with the oil sand and to transfer the restaurant road surface mixture to the roads:

- o front end loader with rubber tires (Cat 975)
- o 2 tandem axle dump trucks (9.2 m^3)
- o vacuum trucks as required (6.2 m^3)

Road Surfacing

The following equipment and crews is used to spread and compact the oily sand/gravel mixture to make the road surface:

- o 3 graders
- o 2 'wobbly wheel' packers with tractor
- o 1 'sheep's foot' packer (if road bed requires major upgrading)
- o 1 smooth drum vibrating packer
- o 1 'rotavator type' mixer with tractor
- o 1 self propelled mixer (required when ripping up previously surface roads)
- o 3 flag people and a laborer to pick rocks

4.4 CAPITAL AND OPERATING COST ESTIMATE

The following cost estimate information was submitted by Esso.

Overall cost (9 m @ 14 m wide roads)

(a)	to remove old road bed	$8 000/km
(b)	new lift (40 cm) (may use 2 - 3 lifts)	$18 000/km

Costs per cubic meter of surfacing

Haulage to ecology pit	$2.50
Pit to road haulage	7.00
Road surfacing	46.00
Gravel (purchased) and mixed	9.50
Supervision	5.00
Ongoing monitoring and testing allowance	5.00
	$75.00/m^3

These costs do not include the cost of gravel as it is required on the roads in any case. Road development is similarly excluded. In addition, no credit is claimed for decreased site road maintenance costs. Reclamation is excluded since it would eventually be required on roads regardless of the construction materials. Overall, the use of oily solids in road surfacing is an effective use of site materials.

No leaching into groundwater of phenols and heavy metals is anticipated. More work in this respect will be done in the future (i.e. approximately $5.00/m^3 added to the present cost).

SECTION VI

SCOPE OF FIELD ASSESSMENT

SECTION VI

SCOPE OF FIELD ASSESSMENT

1 OBJECTIVE REQUIREMENTS OF THE FIELD ASSESSMENT PROGRAM

The following section describes the problems which must be resolved during a test program so that bench scale or other testing can be developed into a commercial plant. The extent of these would not be known until the details of the test plant are known in the case of the Fluid Bed Combustor. The basic information listed below applies in some aspect to all of the processes evaluated and is intended as a guideline for development of specific test programs later. All of the parameters described below are typical for process design and scale-up. They are specific to the appropriate processes.

Basic Design Criteria

The following basic process criteria must be established for the wide range of feed quality in the test plant for STS or fluid bed combustor type of process technologies:

- Material Balance, including solids, water, off-gas and hydrocarbon liquid effluent. First the balance should be established around the entire plant, then around each major piece of process equipment. Test should then be done to establish repeatability of the results. Having done this, optimization of the process should take place at the expected average feed. Flows must be measured accurately. These parameters also apply to the hydraulic facture (hydrofracture) process.

- Process Optimization, would include throughput to produce environmentally acceptable effluents and processed solids. If the process recycles water, then test runs should be allowed sufficient time to reach equilibrium. If chemicals are used, optional quantities and types of chemical additives should be established, so that accurate operating costs can be ascertained later.

- Process Mechanisms for separation must be established in order to scale up pilot plant data in the case of STS. These include, but are not limited to:

    - Temperature;
    - Heat transfer rate;
    - Emissions and effluent quality;
    - Burnout rate in the case of fluid bed combustor;
    - Work index;
    - Energy in/out (efficiency);
    - Separation rates/settling rates of various phases;
    - Separation area/volume;
    - Coalescing and emulsion forming characteristics;
    - Specific gravities, viscosities and surface/interfacial tension of components;
    - Aeration (if required);
    - In the case of hydrolic fracturing, injection rate and ability to sustain injection are important.

In this respect, it is worthy to note that aged material, and oil wet solids would require more agitation (mechanical and fluid-jetting) and heat (energy) to substantiate oil-solid separation in a hot water process such as STS.

- Energy Balance - Process heat, electric power and air will usually be available in excess at the pilot stage. Their

actual requirements should be determined for scale up. Heat transfer rates and coefficients will be important for feed of various qualities. High, average and low energy balances will be required for scale up. Similarly, corresponding material balances must be established for difficult, average and easily processed feed. This is especially important for fluid bed combustion and relevant for STS and hydraulic fracturing;

- Mass Transfer Rate - would be calculated if a solvent were used in the process. In the case of the fluid bed combustor where high temperatures are involved, flashing and burnout would be assessed and controlled. In the case of the STS, hydrocarbon transfer from solid to aqueous phase along the processing path should be assessed;

- Solids Handling - must be considered in all cases from the feed through to the produced residuals. Pumps, conveyor piping, classifiers, conditioners, settlers, etc. must be capable of handling the feed in an orderly, continuous, trouble free manner. The pilot will give insight to materials handling problems. Separators may contain mechanical or hydraulic rakes, augers, jets, steep/shallow walled sumps, etc; all of which will be part of the commercial design;

- Mechanical Equipment - should be selected for its durability and the appropriate design calculations done so that design parameters can be established during pilot testing.

- Operability and Maintainability - is the process relatively simple, easy to maintain and is the equipment

commercially available, or is it prototype? Wear patterns should be established if possible. Any wear would be noted.

2 PROCESS DESIGN BASIS AND REQUIREMENTS

The following section describes the design basis for a field assessment program. The major objectives of a field test unit would be to demonstrate viability, and provide design information for a commercial size plant. In this respect, several of the processes being considered have already been field tested in similar applications. The AOSTRA Taciuk Processor (ATP) is available to demonstrate its capability and viability with respect to oily solids processing and now appears to be far advanced over the fluid bed combustor as far as development is concerned. Pacific Environment Systems and their partners insist on small scale testing before they begin to define their equipment. This could well become a long drawn out process. Esso Resources Canada Ltd. has developed two processes and field tested both; namely "Oily Sand Road Application" and "Oily Sand Processing Plant". Both processes have been proven viable for their Cold Lake site and would not require further testing for any other heavy oil cleanup application. However, monitoring of leaching and groundwater contamination would be worthwhile at this stage. The fluid bed combustor test outlined by Pacific Environment Systems Inc. would give basic design information as to whether the material would burn, how much supplemental fuel is required, stack gas clean up requirement for these specific small burners and general chamber, plenum and ducting sizing. However, the very small size of the test unit may not be as easily scaled up with respect to the burners and the ultimate stack effluents. Pacific Environment's unit is not mobile whereas an ATP unit would be.

Hydraulic fracturing would basically be a full scale test which has been done many times before. A repeat test is not likely to yield any new information.

2.1 SIZING BASIS FOR THE FIELD TEST UNIT

Scale-up is a major consideration in sizing a field test unit (FTU). The commercial size plant will indicate the size of the FTU required. The current commercial production of oily solids is about 70 000 m^3/yr which cannot all be economically transported to a single location. If a commercial plant were sized to operate year round, it could expect to process material for about 4 200 hours per year (considering materials handling, batching, maintenance, etc.). As a stand-alone facility it would not be practical to only operate during the warmer months then lay the staff off during the winter. As an add-on facility it would be acceptable. Incorporating within the processing plant initially would result in the smallest plant and obviously the most economical.

A typical size calculation for a commercial solids processing plant would be as follows:

Assumptions: The plant would have an annual vacation shut down of three weeks. It would operate three shifts per day, five days per week. A planned maintenance program of one shift per week would result in a high availability level. Another fifteen days per year would be lost due to delivery constraints in handling oily solids to the plant. An average feed efficiency of 90% of the maximum feed rate would be achieved to account for decreased rates at startup and shutdown. The plant capacity can then be calculated as follows:

o	Total number of days per year	-	365
o	Scheduled holidays and vacation	-	(26)
o	Unscheduled shipping delays	-	(15)
o	Planned maintenance	-	(15)
o	TOTAL operating days available		309
o	Weekends		(104)
o	DAYS OPERATED/YEAR		205
o	Days operated (in hours)		4 920
o	Mechanical availability		0.85
o	HOURS OPERATED/YEAR		4 182
o	Plant Feed (Current)	-	56 000 m^3/yr
o	Plant Feed Rate	-	13.4 m^3/h

Even if the facility ran during the warm months, it would process 25 m^3/h which is very small by mineral processing plant standards (i.e. on the smallest end of the commercially available equipment).

As examples, the smallest practical conveyor size is 46 cm which can carry 50 m^3/h. Small slurry pumps are 25 mm which pump 60 gpm or 12.1 m^3/h, about 50% by volume of which could be solids. Therefore, the choice of size of demonstration plant is dictated by the smallest size of equipment which is available, and the operation quantities of produced oily solids.

The operations commonly produce as little as 1 m^3/h at many sites and as much as 10 m^3/h in the Sask-Alta Cooperative waste disposal area.

Having considered the above information, the demonstration STS or Fluid Bed Combustor field test unit should be sized at the 1 m^3/h rate and should be utilized later as a commercial unit. It should therefore demonstrate commercial viability at this feed rate.

2.2 DURATION OF TESTING

In order to demonstrate viability, the process must be found to be reliable (i.e. the results must be repeatable and consistent), operable and maintainable. The steps required to demonstrate viability are generally as follows:

	DAYS
(1) Site Erection (skid mounted)	2
(2) Checkout and Startup	5
(3) Plant Familiarization (to train operators)	5
(4) Material Balance Testing (IN must equal OUT)	10

Sample points and sample methods must be confirmed.

(5) Process Optimization	10

Best results should be achieved based on operating parameters such as retention time, energy input (air, heat, steam), degree of dilution, chemical addition, etc.

(6) Repeatability of Results	5

Process parameters are set at constant feed rate and close to average feed quality to establish repeatability.

(7) Operability	20

A wide range of (very "good" and very "bad") feed quality should be processed to establish the capability and flexibility of the process.

(8) Maintainability 3

During operation, maintenance and breakdown records should be kept on the plant. Once testing has been completed, the pumps, etc should be opened up and checked for wear. The test period may be too short to indicate wear, however, if wear does show up it may be a sign of things to come.

TOTAL TEST PERIOD DURATION 60 DAYS

Working five days/week with time off during holidays, this amounts to about three months. Each specific technology will have its own program outlined in Section VI 6.0.

2.3 FEED SPECIFICATION

From the information submitted by the CPA members, it is obvious that a wide range of quality exists from one operation to the next. In order to develop a successful processing system for hot water extraction and more critically for fluid bed combustion and road surfacing, the oily solids must become a managed product. The various ecology pits should be scheduled for "pickup" and the feed blended. Each operator should provide an analysis of approximately what will be delivered to the processor. Liability at a central processor will be difficult to determine unless the operation is managed by a jointly owned company consisting of all the contributors to the feed. This will be particularly important in the case of the fluid bed combustor.

A typical feed would vary widely in composition. A key to successful treating will be the processes ability to handle a wide range of feeds. An average feed will be about as follows:

Hydrocarbon	12.5%
Water	7.5%
Solids	80%

Hydrocarbon Composition (8.2 API)

Asphaltenes	15%
Asphaltics	35%
Aromatics	15%
Resins	15%
Heavy metals - Vanadium	150 ppm
- Nickel	80 ppm
- Iron	500 ppm

Water Composition

- High in sodium and potassium sulphate, chloride and bicarbonate
- Typically - 2 000 ppm chloride, but certainly variable to 20 000 ppm

Solid Composition

- Quartz sands 70-90%
- Clays - Kaolinite 12%
  - Illite 4%
  - Smectite 2%
  - Feldspars 2%
- Sometimes mixed with gravel at the wellheads or in the ecology pits.

2.4 PRODUCT STREAM SPECIFICATIONS

Due to the varied response and the lack of specific feed information, the product stream specifications cannot be accurately determined without testing. This is also reflected in the technology proponents responses. The responses from each technology selected were as follows:

Halliburton

- o inject whatever in fed, + 1/4" cleaned in hot water and used for site reclaimation

ASTCO

- o + 2" cleaned in hot water and used for site reclaimation
- o solids less than 0.5% hydrocarbon (hydrocarbon being the same as that in the feed)
- o water effluents will be reinjected
- o hydrocarbon phase could be as low as 0.5% BS & W.

Pacific Environment Consultants

- o + 3" screened and land filled raw
- o burned solids would have residual ash coating and would be gray to black. Would likely be unslightly similar to coal. Landfills would cover residual solids
- o air effluents would be 0,092 g/m^3 of particulates
- o CO, NO_x, SO_x would be to government guidelines
- o without testing, none of these have been substantiated.

Road Surfacing

- o would meet government leachate guidelines when practised properly

No process is singularly risk free. Ultimately it will be up to the respective governments as to where the effluent shall be placed (air, landfills, or ground?).

3 REGULATORY REQUIREMENTS

Regulatory requirements for field testing can be categorized in the following areas:

- Operation Related
- Feed Transportation
- Effluents Discharge

Operating requirements typically include:

- License to operate the facilities,
- Health & Safety regulations, such as NFPA (fire protection), Class I, Div. 1 design for Fluid Bed Combustor as an example, WCB compliance, etc., and
- Design related regulations such as Pressure Vessel & Boiler code, steam ticket, welder qualifications, etc.

The technology proponents and contractor for the Phase II and III project are jointly responsible for securing the required permits.

Feed transportation, if beyond the heavy oil plant boundary, will be governed by TDGA.

Effluents discharge or in essence, the environmental requirements are governed by Clean Air and Clean Water Acts (as

appropriate to the particular technology) and potentially the following:

- Hazardous Chemicals Act, including Hazardous Waste Regulations;
- Public Health Act, specifically Waste Management Regulation;
- Special Waste Management Corporation Act; and
- Occupational Health & Safety Act.

Guidelines for Land treatment and for Industrial Landfills are also useful and may be referred to.

4 DESIGN CONSIDERATIONS

Design considerations for the field test programs specifically related to the selected processes are outlined below.

4.1 S.T.S. SOLIDS TREATMENT SYSTEM

The S.T.S. commercial plant located at Barnwell (near Taber), Alberta is fully booked for the next two years, processing solids from Saskatchewan, Montana, B.C. and Alberta and they are not able to interrupt that schedule for a test. ASTCO have a 51 L/h unit which they do not feel is of suitable size to demonstrate process capability for oily solids and sludges in the heavy oil area. They are prepared to negotiate a full scale (5 m^3/h) test with their next STS-1000 sale if it is acceptable to the client. Having considered the above, Monenco and Raymond Mineral Dressing

Consultants recommend that a 1 m^3/h unit be built and tested. This unit would be suitable for use later on for smaller site cleanup or for permanent incorporation at one of the plants.

The skid should be modular and should be fully instrumented so that design of the 5 m^3/h incorporates a proven control system. An earthfill ramp could be constructed to the head end of the module so that a bobcat could feed the pilot. The produced solids would be loaded onto trucks and disposed of in a nearby landfill. Electric power and steam should be available at the battery (440 V, 3 PH, 125 AMP).

Overall, the program would be carried out as per Section VI 2.0 to confirm process parameters more so than physical design requirements since a commercial unit is already operating.

4.2 FLUID BED COMBUSTOR

Pacific Environment Systems Inc. propose small scale tests in a pilot plant located in Idaho.

The purpose of these tests would be to determine feasibility of combustion and/or gasification of the oil soaked clay material. The in-bed tube density requirements and char losses were to be analyzed relative to mass balance calculations. Emission levels were to be obtained for consideration in the process flowsheet development.

Since this is a first off application for them, they appear to be starting from basics and the process involved to commercial design could be lengthy.

Perhaps a better solution would be to consider modifying the Taciuk processors to act as a kiln and burner with stack gas cleanup rather than the much more expensive oil recovery.

4.3 PRODUCED SAND REPLACEMENT/RE-INJECTION

Halliburton proposed a 250 m^3 test be run this summer at a cost of about $30 000 for Halliburton and another $100 000 for permits and support. If the well bore has to be reworked the cost would be:

Full bore packers	$7 000
3½ tube string	$5 000
Rig	$3 000
Logging	$2 000
Wellhead rental (4 days)	$2 000
Completion	$8 000
	$27 000

Since re-injection is already being tested by Mobil and is a well proven technology, there seems to be little to gain with another demonstration.

4.4 ESSO ROAD APPLICATION

Esso's road surfacing techniques provide a sensible use of the available resources for improving the roads within the heavy oil operators site. Their technique is well documented and the resulting roads can be reclaimed. The only technical question outstanding is whether the hydrocarbon will migrate into the groundwater. Perhaps several test sections should be monitored to

demonstrate what occurs. Sask-Alta Waste Disposal Cooperative has already conducted similar tests for road oil application. These programs could be used as a guideline for road surfacing test sections.

4.5 MODULARIZED SKID DESIGN

Since the commercial size plant or plants will be very small, they lend themselves to modularization. Modules have several advantages over conventional construction; the most significant of which, is their cost. Shop construction is about $40/h compared to field construction of $60 to $70/h all inclusive. Shops have a better working environment with more sophisticated tools which will result in a less expensive product, even though it may be structurally heavier, productivity will be higher. Modules can easily be manufactured to be portable so that a small plant can be disassembled, moved and reassembled in a matter of days. Skids can be stacked with fold down walkways or walkways and stairways between. If a portable steam plant or electric heat is used along with the process, the modules can easily be winterized. Portable conveyors and hoppers (similar to those used in the sand and gravel business) are manufactured by numerous companies and are very competitively priced. One of the few disadvantages is that an explosion-proof (Class I, Div I) environment requires large plugs and a remotely located control room and MCC. This can be overcome by housing the motor controls and electronics in a separate trailer with a tech cable corridor (on the ground) from the modular plant.

Module size must be limited to 3.7 m side to move freely on highways, or 4.3 m wide with pilot cars. Wider modules would require special transport permits and restricted night movement. Nothing in this size of plant would restrict the weight or width of modular design. Rail transport of very large modules can

accommodate 6.1 m wide, 6.1 m high by 30.5 m long with weight limits to 200 tonnes.

Another advantage of modularization of a relocatable plant would be that it could be assembled and "check out" tested in the manufacturers shop or yard. It also could be manufactured during the "slack season" which would result in a further cost savings. A partial list of potential fabricating facilities would be:

Northern Steel Fabricators	-	Edmonton
Eskimo Steel	-	Edmonton
Dominion Bridge	-	Nisku
Geco	-	Calgary
El Russ	-	Calgary
Fazolli Brothers	-	Calgary
Sulivan, Strong, Scott	-	Calgary and Winnipeg
ProPack	-	Airdrie

During times of high labour utilization (potentially that during peak of Husky Bi-Provincial Upgrader construction) modular fabrication may be the only economical alternative to high remote construction labour premiums.

5 OPERATIONS AND MAINTENANCE REQUIREMENTS

A field test program requires some thought as to how it would be operated and maintained. Each of the four technologies has a unique approach so they are addressed specifically.

All testing would require arranging feed so that an average, best case and worst case oily solids would be collected and transported to the appropriate site. A project manager would be

appointed who would coordinate work with the oil companies, arrange for front end loaders and hire local truckers to transport samples as required. In the case of the fluid bed combustor, the samples could be shipped by truck in bulk or in drums. A broker would have to be hired to clear samples through U.S. customs.

For site testing at Lloydminster (STS or Halliburton) the project manager would arrange for office space, and a front end loader to feed solids to the test unit. The technology proponents would supply staff to adequately demonstrate technology in all cases. A process engineer and operators would be required to run a field test unit STS and to take samples for testing.

If a fluid bed test were carried out in Idaho, the project manager would observe testing, take independent samples (for confirmation) and report on the test unit performance.

In the case of road surfacing, a project manager could observe the test section, report on monitoring (leach testing, etc.) and develop a photo presentation of exactly how the road surface is produced. In addition he could characterize the road building material and comment on its suitability for other areas.

Halliburton would do a demonstration hydraulic fracture and reinjection which would be monitored and reported on by the project manager.

A good source of summer labor for these projects would be engineering students.

Maintenance should be handled on a site by site basis with the local heavy oil operator or contracted from the nearest community.

6 FIELD TEST PROGRAMS

The following section outlines the field test programs required to demonstrate viability of the various processes. Basically the STS hot water extraction system seems to have potential. The fluid bed combustor potentially requires extensive development. Re-injection and road surfacing have been well proven and do not require further testing.

6.1 S.T.S. SOLIDS TREATMENT SYSTEM

After several discussions with ASTCO, the recommended test program to demonstrate viability would be to build a 1 m^3/h demo-plant. The cost of such a unit is likely about \$80 000 ± 25%. The field test program outlined in Section VI 2.2 would run for 60 days and test a wide range of oily solids.

6.1.1 Test Sample Sizes

Individual test sample sizes	48 m^3
Total Sample Size	1 440 m^3

6.1.2 Test Parameters

1. Material Balances
   - density
   - flows
   - solids size distributions
   - moistures
   - BS & W (all phases)
   - separation mechanisms
   - aeration (if required)
   - chemicals (if required)
   - recovery

2. Energy Balances
   - temperature
   - coefficients of heat transfer
   - efficiency

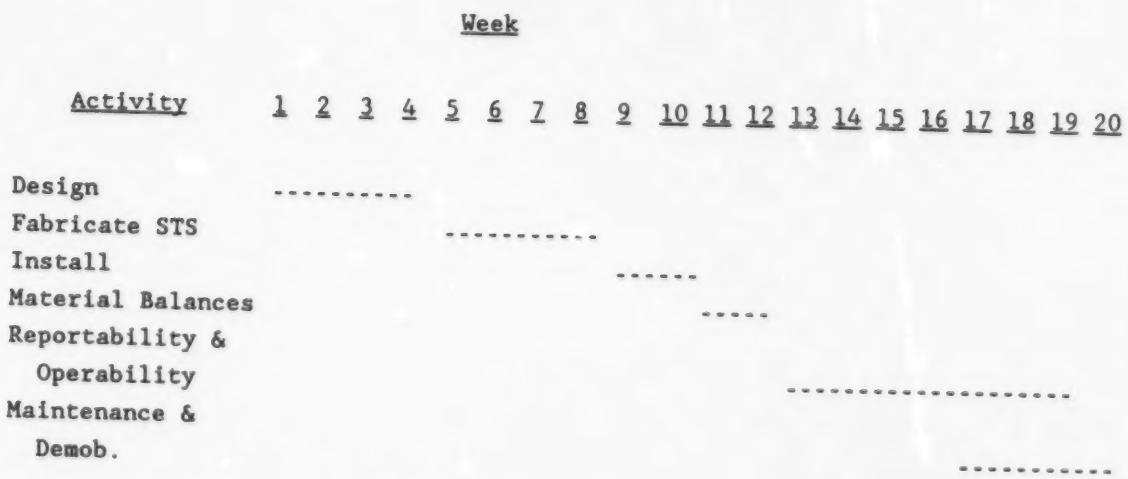
3. Solids Handling Characteristics
   - feed (raw material)
   - oversize removal
   - tailings dewatering

4. Mechanical Equipment
   - auger & pump wear
   - reliability (sustained run)

6.1.3 Outside Battery Limit (OSBL) Requirements

1. Front end loader 60 working days
2. 125 AMP power supply
3. Piping, etc.
4. Water supply (preferably hot)
5. Prepare on natural gas supply
6. Sample analysis by laboratory (2 hours)
7. Fabricator for FTU
8. Oily solids transport 1 440 m^3

6.1.4 Schedules



6.1.5 Capital and Operating Cost Estimate for Field Test

Facilities

A field test facility involves not only the normal operation of a process plant to clean oily solids but also the generation of a great deal of operating information, supporting analyses and environmental observations and reports. This section outlines the cost of the facility, all the infrastructure, support facilities and ancillaries that can be associated with a field demonstration of either the STS; and fluid bed combustion unit. The other test programs are stand alone on remote pilot testing at an existing facility.

BASIS OF ESTIMATE

Assumptions

In the development of the estimated costs, a number of general assumptions were made which reflect current market conditions. These assumptions are as follows:

- o first half 1990 Canadian dollars;
- o modularized construction with minimum on site erection required;
- o site prepared by local contractors and suitable for summer test period;
- o support services available from main processing plant;

- borrow material is available near the site for site grading, ramp to STS and cleanup;
- construction labour based on Alberta labour rates;
- plant operators are summer students from tech or university;
- no housing cost is to be associated with the project;
- Engineers are provided by the CPA members and are charged to the project at $10 000/month including all expenses;
- maintenance personnel (electrical, mechanical, instrumentation and welding) are available from the main plant on an as needed basis and charged to the project at an all up rate of $30/h;

Estimate Methods

The estimating methods selected for this study were designed to provide a responsive budget estimate suitable for request for funding. This section describes the means used in providing estimates of capital and operating costs.

Operating Cost of Field Test Unit (1 m^3/h, STS or Fluid Bed Combustor)

The operating cost of a 1 m^3/h demonstration field test unit has been built up from basic principles and assumes the program would be done fast and efficiently. The 60 day duration applies.

Manpower

Project Manager and Principle Engineer (5 months)	$50 000
Proponent Principle Engineer (may be supplied at no cost)	$50 000
Process Engineer (junior - 4 months)	$20 000
2 Operators (students - 4 months)	$19 200
Maintenance 80 h (TOTAL) @ $30/h	$2 400
(most maintenance done by operators)	
TOTAL LABOUR COST	$141 600

Maintenance Plants

Allowance for replacement and changes	$15 000

Power Costs

56 kW at 4.0 ¢/kW	$1 050

Reagents and Supplies

o none anticipated at this time for STS (but allow)	$500
o fluid bed combustor would require caustic	$500

Equipment Rentals

Bobcat (Certified Rental) 4 months @ $1 900/mo	$7 600
Van 4 months (AVIS) @ $800/mo + $0.15/km	$5 000
Fuel, etc.	$1 600
Tools	$2 000

Laboratory Analysis (AGAT)

1400 BS & W	@ $24	$34 560
120 Dean & Stark	@ $20	$2 400
60 Sieve Analysis	@ $55	$3 300
Misc.		$5 000
Trucking	1,440 m^3 @ $10/$m^3$	$14 400
Final Engineering Reports		$20 000
TOTAL OPERATING COST		$254 010

Capital Cost

The capital cost on 1 m^3/h STS unit is probably $80 000 to $100 000. A fluid bed combustor with all of its air cleaning equipment would likely cost $500 000 to $900 000 and has been approximated by Pacific Environmental Consultants Ltd. It would be reasonable to consider building STS unit for testing, however, the pilot fluid bed combustor in Idaho would be more cost effective for that process.

6.1.6 Test Program (Mini-Pilot Plant)

A mini-pilot plant is available for testing but not recommended.

The field test will be conducted in 2 batches which consists of 3 different samples. After having the results of the first batch, there would be a duplication test for confirmation purposes.

Each set of samples would represent different Oily Solid characteristics. The test would be conducted on ASTCO's portable test unit in that Lloydminster area. To provide good test results each sample would have to be processed for at least 48 hours at the proposed rate of 0.05 m^3/h since the retention time in the unit is about 24 hours.

Test Sample Sizes

Individual test sample size	2.4 m^3
Total Sample Size (6 feeds)	14.4 m^3

Test Parameters

The following parameters will be monitored during the testing program.

1. Processing Vessel : Temperature for each Chamber
   Energy Requirement
   Effective Flow Rate
   Overall Material Balance

2. Oil Phase : Chemical & Physical Characteristics

3. Aqueous Phase : Chemical & Physical Characteristics

4. Solid Phase : Chemical & Physical Characteristics

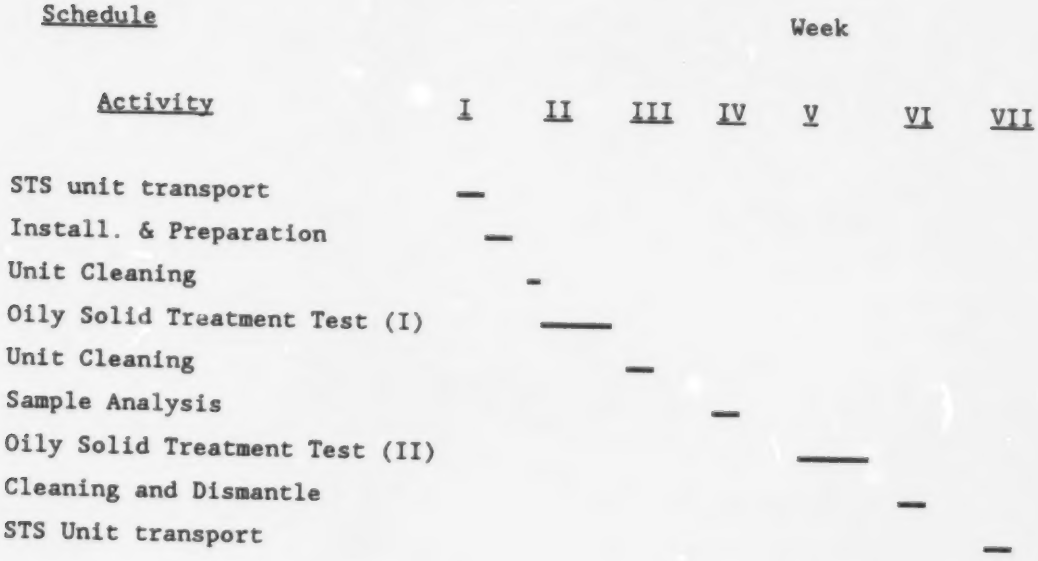
5. Other parameters are outlined in Section VI, 2.0.

Outside Battery Limit (OSBL) Requirements

1.	Front end feed system (hopper etc.)	20 days
2.	Electrical power supply	50 Amp.
3.	Piping etc.	
4.	Sample analysis by laboratory (hourly)	288 samples
5.	STS unit transport (Taber-Lloyd vv.)	1 500 km
6.	Oily solid transport	14.4 m^3

Estimated Schedule and Costs

Schedule



Estimated Testing Costs

1. Facilities

STS unit rental including 2 full time - ASTCO operators (20 days @ $1 000/d	$20 000.00
Piping & installation allowance	5 000.00
SUBTOTAL 1.	$25 000.00

2. Support & Consumables

Sample analyses (288 spls. @ $90.00/spl)	$25 920.00
STS unit transport (1 500 km. @ $0.75/km)	$1 125.00
Electrical power supply 50 Amp. (by operator)	$0.00
Oily solid transport (15 h @ $55.00/h)	$825.00
Front end feed system rental allowance & operating supplies	$5 000.00
SUBTOTAL 2.	$32 870.00
TOTAL TEST PROGRAM COST	$57 870.00
Reporting of Results & Recommendations	$20 000.00
TOTAL OPERATING COST	$77 870.00

6.2 FLUID BED COMBUSTOR

Due to the lack of development of a fluid bed combustor, Pacific Environment Systems Inc. proposed a very small scale test burn in Idaho.

The test would be conducted on 3 different samples in duplicate. Each set of sample would represent different Oily Solid characteristic.

To provide a good test result each sample would have to be processed for at least 2 hours at the proposed rate of 1 m^3/h.

6.2.1 Test Sample Sizes

Individual test sample size	2 m^3
Total Sample Size (6 units)	12 m^3

6.2.2 Test Parameters

The following parameters would be monitored during the test program.

1. Combustion Chamber : Process Performance Information (Combustion temp., Thermal balance, etc.

2. Stack Gas : Gas emission chemical characteristics (NO_x, SO_x, CO, O_2, etc)

3. Gas Bag Chamber : Produced solids' chemical characteristics

6.2.3 Outside Battery Limit (OSBL) Requirements

1. Labour Support (Assistant) 4 md.
2. Oily solid transport 12 m^3

6.2.4 Estimated Schedule and Costs

Time Schedule

Activity	Duration (days)	Elapsed Time (days)
Oily Solid transport	2	2
Oily Solid Combustion	4	6

6.2.5 Estimated Testing Costs

1. Facilities

PES equipment rental (4 days)	$22 000.00
Labour Support (Assistant)	$0.00
Oily solid transport (600 km @ $0.24/$m^3$.km)	$1 728.00
Customs Clearing	$1 000.00
Final Report	10 000.00
TOTAL TEST PROGRAM COST	$34 728.00

6.3 PRODUCED SAND REPLACEMENT/RE-INJECTION

The cost of a 250 m^3 test program was developed from the detailed estimate in Section V. The cost summary is as follows:

Halliburton Cost	$30 000
Support and reporting	$100 000
Well prep and completion	$27 000
TOTAL PROGRAM	$157 000

Re-emphasizing that the technology is well proven and the best "cradle-to-grave" approach to disposal, re-injection would be best suited to dispose of the materials not suitable for road surfacing. Road surfacing requires selected sands while hydrafracing could handle organic solids, oily tap soil, tank bottoms and other sludges. The best fit for heavy oil operations is possible a combination of hydraulic fracturing and road surfacing.

6.4 ROAD SURFACING

Road surfacing as practised by Esso Resources at Cold Lake is successfully utilizing the available resources and improving vehicle movement on the lease. Dust from gravel roads is eliminated and site road maintenance costs are reduced. Roads developed in this manner are fully reclaimable.

The only outstanding item is a comprehensive test program to demonstrate that groundwater contamination is not a factor. The Sask-Alta Waste Disposal Cooperative have conducted several studies relevant to the possible effects of hydrocarbon migration. "Potential Effects of Oily Waste Disposal on the Terrestrial Environment - An Overview", SRC, July 1988. They have considered which leachate studies at which pH levels are likely appropriate. The study verifies that heavy metals in the mineral matter is not released to the soil solutions and is not available for uptake by plants. Road solids salt contents are generally below 1 000 ppm with a maximum of 2 000 ppm. Using hot sand in the winter instead of salt insure that adjacent plants will not be salt stressed. The levels of mercury and nickel (page 32) would limit the application of oily waste to nine treatments at the rate of 80 m^3/km of road if the reclaimed road were to be used for agricultural purposes. Levels of 0.5% oil or less appear to stimulate plant growth (page 40). As a result of SAWDC studies, it appears unlikely that a properly surfaced road would ever present an environmental hazard.

A suggested test program might be for each operator to set up a test road section where surface water and ground water samples are taken periodically to demonstrate possible contamination. These

test sections should be sampled 1 year prior to surfacing to establish a base line from which to work. The guideline for livestock and wildlife watering, as compared to the Canadian Drinking Water Standard, (mg/L) might be the acceptable limit. This guideline is as follows:

	mg/L	Canadian Drinking Water Standard (mg/L)
Aluminum	5.0	-
Boron	5.0	5.0
Cadmium	0.01	0.005
Calcium	1000	80-100
Cobalt	1.0	-
Copper	0.5	<1.0
Chromium	0.05	0.05
Iron	0.3 *	<0.3
Lead	0.05	0.05
Molybdenum	0.01	-
Nickel	0.025 *	<0.025
Vanadium	0.1	-
Zinc	25	<5.0
Chloride	250 **	<250
Sulphate	1000	500
Nitrate	20	10
pH	6.5-9.0 *	6.5-8.5
Phenol	0.001 *	<0.001
Arsenic	0.05	0.05
Selenium	0.01	0.01
Mercury	0.003	0.001

* Not included in Guidelines for Livestock, but is included in Guidelines for the protection of freshwater aquatic life.

** Maximum acceptable levels in water used for domestic consumption (not stated in livestock or wildlife guidelines since salts form a part of their diet).

The keys to a successful road surfacing program as emphasized by Esso Resources, Cold Lake personnel are management of the ecology pit materials, management of the surfacing, proper drying and compaction (so that the final cap acts as a sealer and a caring attitude towards the environment during the various phases of construction, maintenance and finally reclaimation.

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

After evaluating some 34 processes and techniques for cleanup of oily solids from heavy oil operations, 3 emerging technologies along with Esso Road Application were selected as the potentially most promising solutions to the problem. The base case and current practice was road surfacing which was reviewed in detail with Esso Resources Canada Limited. Hydraulic fracturing by Halliburton was also selected as a proven technology with the best possibility of "cradle to grave" disposal. Alberta Solids Treatment Company offered a hot water extraction process combined with an API separator which would reclaim the oil and scrub the solids so that they would be acceptable for a Class II landfill. J.W.P. in conjunction with Pacific Environment Systems offered to test some of the oily solids material in a small pilot fluid bed combustor in Coeur d'Alene, Idaho. The results of their testing would then be used to make recommendations for a commercial size fluid bed combustion unit. The Taciuk processor, although not selected as one of the final four technologies has already demonstrated technological capability of providing a solution to both oil recovery and solids disposal for Class II landfill.

Based on the information submitted by the proponents, by far the most cost effective method of oily solids disposal is that currently practices by Esso Resources Canada Limited which is road surfacing. The cost of road surfacing is about $\$75/m^3$ including reclamation and ongoing monitoring. Fluid Bed Combustor and STS Hot Water Extraction offer alternative solutions at about $\$105/m^3$ with acceptable solids residuals being disposed of in a Class II landfill. Halliburton hydraulic fracturing would result in the best "cradle to grave" solution to disposal at a cost of about $\$136/m^3$. From this study it is clear that the most cost effective solution is the current practice as demonstrated at Cold Lake.

Recommendations with respect to these technologies are outlined in the following points:

- Road surfacing as practiced by Esso Resources, which is totally supervised and managed from ecology pit to ultimate blending of gravel on the road surface, appears to be a very acceptable solution to oily solids disposal. Heavy oil operations all require roads within their lease boundaries. All roads surfaced in this manner can be ripped and spread and will revegetate naturally. With current reclamation practices, roads can be reclaimed to very acceptable levels. Leaching tests will be initiated to ensure that ground water is not contaminated with phenols or heavy metals. No problems in this area have been observed. Road surfacing within operator's lease boundaries results in safer roads for travel on the sites and reduces road maintenance costs. It is also a practice of effective utilization of resource materials available in a heavy oil operation. Esso Resources Canada Limited would be pleased to show any other interested heavy oil operators what there practices are. Like any other process, sound management and excellent application techniques result in an excellent product;

- The hot water extraction combined with API settler as submitted by Alberta Solids Treatment Company provides an opportunity to reclaim the oil and scrub oily sands at a cost of about $\$105/m^3$. In order to prove this technology a field test unit should be manufactured which will proces s about 1 m^3/h of oily solids. This process would result in a hydrocarbon product which contains less than 0.5% BS & W and treated solids which contain less than 0.5% hydrocarbon. The solids would still have to be disposed of in a Class II landfill or land farm application as

practices under an Alberta Environment permit. From an environmental viewpoint, the benefit of this type of process is that the solids are disposed of in a more manageable, smaller, confined space. The ultimate disposal still has all the inherent risks of landfills in the future. The capital cost of a field test unit would be in the order of $100 000. The operating cost of a field test program carried out over a three month period would be about $250 000. A test program using the existing small STS unit which would only process about 14.5 m^3 of oily solids in total would likely cost about $80 000. However, it would probably result in an unfavorable decision or leave a large number of design questions unanswered with respect to scale-up to the commercial unit;

- The Fluid Bed Combustion pilot plant in Couer d'Alene, Idaho may be too small to adequately demonstrate the design parameters necessary to produce a commercial scale fluid bed combustor. In addition, very little effort was put in to developing the capital cost of such a commercial scale unit, so there is considerable risk that the costs projected for this facility are grossly underestimated. At any rate the combined capital and operating cost of a fluid bed combustor based on preliminary information is about $105/$m^3$ with very little opportunity for cost improvement. Ultimate disposal of the residuals still requires a Class II landfill, with the added environmental risk of air pollution containing heavy metals, carbon monoxide, and sulphur dioxide. Considering that the facility would have to be fixed, some of the outlying heavy oil operators would incur a considerable expense of trucking ecology pit wastes to the fluid bed combustor site. Increased moisture contents in the feed would

result in much higher quantities of supplemental fuel being required to drive off the water vapour. An extensive scheduling and blending facility would be required to keep an uniform feed to the unit. Stack gas emissions would be difficult to monitor on anything but a long term basis with intermittent samples (say quarterly);

- An excellent alternative would be the AOSTRA Taciuk Processor (ATP) which has already proven capable of processing oily solids and sludges. Conceivably field testing on ATP can also be done in parallel with testing of STS and Fluid Bed Combustor. Results from ATP would be used as the basis for assessment;

- Hydraulic fracturing as practised by Halliburton provides the best cradle-to-grave solution to oily solids waste disposal in that the materials are returned approximately to their place of origin. A commercial operation reinjecting about 40 000 m^3 per year of the worst oily solids could be accomplished at a cost of about $\$136/m^3$. The technology is well proven and does not need to be demonstrated in the field test program;

- Perhaps the best solution for all of the heavy oil operators collectively is a combination of road surfacing with managed oily solids which are acceptable for road surfacing and the remaining oily solids containing soils, clays, organic materials and fine silts might be set aside for a hydraulic fracture program. A combination of the two would result in the cleanup of the oily solids from all of the heavy oil operators regardless of the oily solids quality. This may ultimately be the most cost effective environmental program as well. The key to oily solids cleanup is the management of the wastes being

disposed of and the management of the processes of disposition whatever they might ultimately be;

- Consideration was given to smaller sized units (1 m^3/h) as opposed to a larger 10 m^3/h unit. However, the support equipment and operating staff would render such a unit uneconomical. A better small unit approach would be to incorporate the processor in the existing plants;

- Consideration was also given to a regional processor as opposed to a mobile processor. The problems with a regional stationary unit such as the fluid bed combustor system are the higher transportation costs from outlaying areas and the common liability for the residual material being placed in a single common landfill or whatever. In general, the operators do not want to accept common liability.

APPENDIX A

INVITATION PACKAGE FOR SUBMITTING TECHNOLOGY INFORMATION AND OILY SOLIDS DATA

Monenco
Engineering a whole new world.

1990-01-03
CPA 8601-2/5882

Subject: INVITATION FOR SUBMITTING INFORMATION
"Produced Oily Solids Cleanup Technology"
CPA Ref.: AFE 89-6205-036

Canadian Petroleum Association (CPA) with its participating heavy oil operating companies has embarked upon the Evaluation of New Technologies for Cleanup of Produced Oily Solids from Heavy Oil Operations Project. As a key component of the Phase I work in the three-phase approach, CPA would appreciate the submission of relevant information from a list of approved technology proponents for a comprehensive assessment and screening. The most capable and cost-effective processes or technology packages will be selected. Field testing at major heavy oil production areas and arrangements with the owner companies would be negotiated in Phase II and Phase III in the future.

Concurrent with this invitation package, a national advertisement campaign has been initiated.

On behalf of CPA as the general contractor, Monenco urges that your company provide sufficient information for this highly significant undertaking. We believe it is mutually beneficial to your company and the Canadian heavy oil industry. All information including technical and cost data provided to this Project shall be on a non-confidential basis or is protected by patent(s) or patent application. The attached Information Summary sheets are intended to give you guidelines of submission. Due to time constraint, we would appreciate your response by January 31, 1990.

Canadian Petroleum Association and Monenco Consultants Limited look forward to your cooperation.

Yours truly,

F.H. (Frank) Wu, P.Eng., Ph.D.
Project Manager
Telephone (403) 298-4563 Fax (403) 298-4125

Attach.

Monenco Consultants Limited
400 Monenco Place
801 - 6th Avenue S.W. Calgary
Alberta, Canada T2P 3W3
Telex: 03-822636 MON CGY
Fax (403) 298-4125
Telephone: (403) 298-4170

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company:
Contact Person: Title:
Address:

Telephone: ( ) Telefax: ( )

I TECHNOLOGY DEFINITION

1. Concise Description of the Technology: _____

_____

_____

2. Feed Specifications & Constraints

Solids (%):	_____ (normal)	_____ (minimum)	_____ (maximum)
Oil (%):	_____ (")	_____ (")	_____ (")
Water (%):	_____ (")	_____ (")	_____ (")

Any Constraint in Feed? _____

_____

3. Please Identify Four Key Process Sub-systems.

	Sub-systems	Operating Pressure	Operating Temperature
a.	_____	_____	_____
b.	_____	_____	_____
c.	_____	_____	_____
d.	_____	_____	_____

4. Product Streams Description

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

*Destination Designation (DD):

ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: _____ (Identify Pressure Level)
Hot water or Condensate: _____ (YES or NO)
Utility Water & Cooling Water: _____ (YES or NO)
Potable or Demin Water: _____ (YES or NO)
Fuel: _____ (Identify fuel types)
Chemicals: _____ (Provide generic names)
Blanketing Gas: _____ (Identify the gas, if YES)
Others: _____ (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES ___ (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: _____ (GPM, L/Hr, T/D, etc.)
Test Sites or Feed Sources: _____
Modifications or Improvements Needed: _____
_____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

_____
_____

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based:
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others _____
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $_____
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____%
b. Breakdown

Capitalization	:
Operating Labour	:
Chemicals & Consumables	:
Utilities	:
Maintenance & Replacement	:
Treated Streams Disposal	:

IV DESIGN DOCUMENTS

Please check and include available documents:

☐ : Process Flow Diagram (PFD)

☐ : Material Balance

☐ : Utility Flow Diagram (UFD) & Utility Balance

☐ : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____
_____

☐ : Utility P&ID's or MFD's, giving a list of Titles & Numbers:
_____
_____

☐ : Others, please specify: _____
_____

89-12-21
CPA 8601-2/5893

Attention:

Gentlemen:

Subject: Oily Solids Information

The following information from the heavy oil producers is requested by the Canadian Petroleum Association. The CPA is preparing a study for the "Evaluation of New Technologies for Cleanup of Produced Oily Solids from Heavy Oil Operations". The joint approach is expected to establish capability and location for pilot testing and eventually for full-scale operations. In order to establish the program your cooperation in providing the following information is appreciated.

1. Heavy oil produced - bbls/yr

2. Types and Quantities of Oily Solids;

    - Produced Sands (only those requiring processing) - m^3/yr
    - Sludges (other oily solids generated in heavy oil production - m^3/yr
    - Estimated Current Inventory of Stored Oil Solids - m^3/yr

3. Waste Material Source

    - Location of each type (brief description)

4. Significant Components and Average Concentrations:

    - Inorganic Constituents

        - Clay (type if known i.e. drilling mud)
        - Sand
        - Gravel and Rock (top size)
        - any significant other information or minerals and trace metals.
        - Water

- o Organic Constituents
  - o Oil and Grease
  - o Hydrocarbons
  - o Aromatics
  - o Phenols
  - o Naphthenes
  - o Asphaltenes
  - o Brief comments on the wetability of the solids (i.e. is the solids oil or water wet).
- o Health Hazard and Safety Information
  - o If known
- o Waste Classification
  - o Hazardous, non-hazardous
- o Other Relevant Comments
  - o Any comments about your site which would help screen cleanup processes or assist in site selection.

5. Central Process Facility and Utility Information & Availability

   - o Steam
   - o Condensate or clean water
   - o Electric power (voltage/Ph/Hz)
   - o Air
   - o Mobile equipment to handle plant feed and produced residuals

6. Disposal Preference

   (i.e. Would you like your own residuals returned to you)

7. Distances of Oily Wastes (from your central facility)

   (i.e. to be used in establishing transportation requirements)

We appreciate that all of this information may not be available, however, the more that you develop, the more credence the study will have.

Thank you for your cooperation.

Yours truly,

Frank H. Wu
Project Manager

APPENDIX B

MEDIA ADVERTISEMENT DISPLAY

CANADIAN PETROLEUM ASSOCIATION (CPA)

respectfully requests the submission of information on

Oily Waste Cleanup Process/Technology

- Process/Technology Description
- Feed and Product Streams Spec.
- Operating and Capital Costs
- Status of Development
- Other Pertinent Design and Operating Data

for the evaluation and selection of promising candidates for application to the Canadian Heavy Oil Industry.

For further details please contact the general contractor of CPA by January 22, 1990.

Frank H. Wu, P.Eng. Ph.D.
Monenco Consultants Limited
801 - 6th Ave. SW
Calgary, Alta. T2P 3W3
Tel: (403) 298-4563 Fax: (403) 298-4125

APPENDIX C

"INFORMATION SUMMARY" SHEET FROM TECHNOLOGY PROPONENTS

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

PETROCYCLE inc. GUINARD CENTRIFUGATION
(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company:
Contact Person: FRANCIS SOUCY Title: PRESIDENT
Address: 6500 boul de La RIVE Sud
SUITE 380, LEVIS, QUEBEC G6V 7M5
Telephone: (418) 837-0296 Telefax: (418) 835-6679

I TECHNOLOGY DEFINITION

1. Concise Description of the Technology: 3 phases vertical centrifuge separator placed on a 48 feet trailer (mobile)

2. Feed Specifications & Constraints

Solids (%):	0-30	(normal)	0	(minimum)	45	(maximum)
Oil (%):	0-80	(")	0	(")	80	(")
Water (%):	85-100	(")	0	(")	100	(")

Any Constraint in Feed? If % of solids are higher than 45%, it must be diluted with oil or water.

3. Please Identify Four Key Process Sub-systems.

Sub-systems	Operating Pressure	Operating Temperature
a. Pre heating Tank	70 to 145 PSI	60°-80°C
b. Self Cleaning Filter	—	—
c. Heat Exchangers	70 to 145 PSI	80°C-100°C
d. Dehydration Unit	—	—

4. Product Streams Description

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Oil phase	-1.5 BSW	+98.5		PR	
Water phase	-1.0	-1.0 oil			
Solid phase	60-70	30-40			

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: 70-150 PSI (Identify Pressure Level)
Hot water or Condensate: Y (YES or NO)
Utility Water & Cooling Water: Y (YES or NO)
Potable or Demin Water: — (YES or NO)
Fuel: NO (Identify fuel types)
Chemicals: DEMULSIFYER (Provide generic names)
Blanketing Gas: NO (Identify the gas, if YES)
Others: LEAKPROOF CONTAINERS (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS Canadian Licence obtained from Guilliard Oil Service

1. Registration: NO ___ YES ___ (P/l provide info below) From France
Patent Number(s):
Country(ies) & Date(s):

2. Development Status See appendix on brochure

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: _____ (GPM, L/Hr, T/D, etc.)
Test Sites or Feed Sources: _____
Modifications or Improvements Needed: _____
_____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information. See appendix on the Brochure

Other Information Relevant to Availability of the Technology:

_____
_____

III COST DATA LEASING Base ONLY PRICE per cubic meter of Sludge process

1. Costing Base

a. Size of Unit on which cost estimate is based:
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others _____
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $_____
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____%
b. Breakdown

Capitalization	:
Operating Labour	:
Chemicals & Consumables	:
Utilities	:
Maintenance & Replacement	:
Treated Streams Disposal	:

IV DESIGN DOCUMENTS

Please check and include available documents:

[✓]: Process Flow Diagram (PFD)

[ ]: Material Balance

[✓]: Utility Flow Diagram (UFD) & Utility Balance

[ ]: Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

[ ]: Utility P&ID's or MFD's, giving a list of Titles & Numbers: _____

[ ]: Others, please specify: BROCHURE OF OUR PROCESS

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

* AOSTRA-Taciuk Process *

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: UMATAC Industrial Processes
Contact Person: R.M. Ritcey **Title:** Manager, Demonstration Operation
Address: #210 - 2880 Glenmore Trail, S.E. Calgary, Alberta. T2C 2E7
Telephone: (403)279-8080 local 18 **Telefax:** (403)236-0595

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:** Thermal Treatment, Separation of organics by vaporization and pyrolysis from soils and sludges, recovery and recycling of oils

2. **Feed Specifications & Constraints**

Solids (%):	65	**(normal)**	0	**(minimum)**	100	**(maximum)**
Oil (%):	10	( )	0	( )	95	( )
Water (%):	25	( )	0	( )	95	( )

Any Constraint in Feed? Large objects must be separated in feed preparation to maximum particle/object size of 70mm.

3. **Please Identify Four Key Process Sub-systems.**

Sub-systems	Operating Pressure	Operating Temperature
a. Feed System	N/A	N/A
b. Processor	- 1.5mm H20	260 - 700 °C
c. Oil Recovery	- 1.5mm H20	200 - 500 °C
d. Flue Gas Treatment	- mm H20	65 - 235 °C

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Solids	95	5(1)	0	ED(2)	(3)
Oil	< 1	99	0	PR	(3)
Water	< 1	> 99	0	FT	(3)
Flue Gas	< 100mg/m^3	20	100	ED	N/A

(1) 5 process water added for cooling and dust control.
(2) Solids are free of hydrocarbon. Content of inorganic contaminants in the feed affects disposability directly to landfill.
(3) As per the proportions in the feed.

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: none (Identify Pressure Level)
Hot water or Condensate: no (YES or NO)
Utility Water & Cooling Water: yes (YES or NO)
Potable or Demin Water: no (YES or NO)
Fuel: NG OIL LPG (Identify fuel types)
Chemicals: CaO (Provide generic names)
Blanketing Gas: Nitrogen (Identify the gas, if YES)
Others: * (Excluding plant air & electricity)
* Depending on acidity of feed.

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES xx (P/l provide info below)

Patent Number(s):	CANADA	USA
Country(ies) & Date(s):	1120418	4280879
	1121749	4285773
		4306961

2. Development Status
Proven and demonstrated at commercial scale.
Bench-Scale Test Completion Date: 1989 latest
Demonstration Test
Size of Unit: 10 ~~(GPM, L/Hr, T/D, etc.)~~ TPH
Test Sites or Feed Sources: Alberta/Saskatchewan Oilfields
Modifications or Improvements Needed: none

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.
*** See Attached Page 4

Other Information Relevant to Availability of the Technology:

UMATAC is the developer and manufacturer of plant equipment.
UMATAC can provide commercial field service through affiliates.

III COST DATA

1. Costing Base (Assumptions for Estimating)

a. Size of Unit on which cost estimate is based: 5 or 10 tph
b. Base year: Please base it on 1990 application year. 1990
c. Utility Rates: Electricity $.05, NG (1), Fuel Oil (2)
Coal ___, Steam ___, Others ___
d. Operating Labour Rate(s): $25.50/hour (includes benefits)
e. Capitalization: 25 years on 10% Interest Rate

(1) $5/mm BTU
(2) $.50/L

2. **Capital Installation Cost:** $2 to 5 million
   (Excluding: Royalty, Engineering License Fee & Engineering Service Fees)
   * $2.5 million for 2 tph capactiy, $5 million for 10 tph.

3. **Operating Costs**

	5 tph (1)	10 tph (2)
a. $ (1) /year on Capacity Factor 80(2) %	$2.7 mm/yr	$4.4 mm/yr
b. Breakdown (3)		
Capitalization :	9%	12%
Operating Labour :	41%	37%
Chemicals & Consumables :	20%	20%
Utilities :	16%	15%
Maintenance & Replacement :	10%	10%
Treated Streams Disposal :	4%	6%

IV DESIGN DOCUMENTS

Please check and include available documents:

[xx] : **Process Flow Diagram (PFD)**

[ ] : **Material Balance** - Not available for general consideration - different for specific feeds

[ ] : **Utility Flow Diagram (UFD) & Utility Balance**

[ ] : **Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers:** in final review at UMATAC

[ ] : **Utility P&ID's or MFD's, giving a list of Titles & Numbers:** in final review at UMATAC

[XX] : **Others, please specify:** Plant Layout

(2) 80% of total time is available for plant oepration, downtime (20%) includes all maintenance and operating delays (exluding delays from outside influences)

(3) Costs based on a fixed plant installation.

ALTERNATIVE BREAKDOWN	5 TPH	10 TPH
Capitalization	9%	12%
Operating Labour	41%	37%
Chemicals & Consumables	20%	20%
Utilities	3%	3%
Maintenance & replacement	10%	10%
Treated streams disposal	5%	6%
Other costs	12%	12%

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

NEUTRALYSIS SYSTEM PROCESS

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: Energy Conversion Inc
Contact Person: Dr A Colin Jackson **Title:** President
Address: Suite 625 Atrium II 940 6th Avenue SW Calgary T2P 3E5

Telephone: (403) 266-5965 **Telefax:** (403) 265-6484

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:** Four stage hybrid process which converts fuel pellet consisting of pulverized municipal solid waste mixed with clay to a vitrified inert fine aggregate

2. **Feed Specifications & Constraints**

		(normal)		(minimum)		(maximum)
Solids (%):		(")		(")		(")
Oil (%):		(")		(")		(")
Water (%):	30	(")		(")		(")

Any Constraint in Feed? _____

3. **Please Identify Four Key Process Sub-systems.**

Sub-systems	Operating Pressure	Operating Temperature
a. Pulverizing		
b. Clay Preparation		
c. Mixing - Pelletizing		
d. Pyrolysis Oxidation		

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Aggregate				PR	
Flue Gas				ED	
Thermal Energy				PR	

* Vitrification 1100 - 1200 °C

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: No (Identify Pressure Level)
Hot water or Condensate: No (YES or NO)
Utility Water & Cooling Water: Yes (YES or NO)
Potable or Demin Water: No. (YES or NO)
Fuel: _____ (Identify fuel types)
Chemicals: No (Provide generic names)
Blanketing Gas: No (Identify the gas, if YES)
Others: No (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES ✓ (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date: August 1988
Demonstration Test
Size of Unit: 30 (GPM, L/Hr, T/D, etc.)
Test Sites or Feed Sources: Australia
Modifications or Improvements Needed: _____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based:
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others _____
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $ 1,996,000.00
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____ % $ 36.25 / ton

b. Breakdown

Capitalization	:	$ 898,000.00
Operating Labour	:	$ 632,000.00
Chemicals & Consumables	:	$ 91,000.00
Utilities	:	$ 95,000.00
Maintenance & Replacement	:	$ 15,000.00
Treated Streams Disposal	:	$ 206,000.00

IV DESIGN DOCUMENTS

Please check and include available documents:

☐ : Process Flow Diagram (PFD)

☐ : Material Balance

☐ : Utility Flow Diagram (UFD) & Utility Balance

☐ : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

☐ : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

☐ : Others, please specify: _____

_____

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

Oily Solids Separation (O.S.SEP.) Process
(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: M.G. Engineering, a division of Tzipa Enterprises Ltd.
Contact Person: M. GREENFALD, P.Eng. Title: PRESIDENT
Address: 655 Cedarille Wyn. S.W.
Calgary, Alta. T2W 2G9
Telephone: (403) 251-7744 Telefax: (403) 251-2001

I TECHNOLOGY DEFINITION

1. Concise Description of the Technology: A washing process, involve chemical treatment of the oily solids in aqueous slurry form, facilitating oil/solids separation followed by solids/water separation.

2. Feed Specifications & Constraints

Solids (%):	15	(normal)	1	(minimum)	97	(maximum)
Oil (%):	40	(")	2	(")	98	(")
Water (%):	45	(")	1	(-)	97	(")

Any Constraint in Feed? Solids size & Concentrations dictates equipment selection.

3. Please Identify Four Key Process Sub-systems.

Sub-systems	Operating Pressure	Operating Temperature °C
a. Slurry preparation	Atm.	60 - 80
b. oil/slurry separation	"	"
c. Dewatering	40 psig	"
d. Water Treatment (auxiliary)	Atm	60

4. Product Streams Description

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
(1) Oil	0-2	98-100	—	P.R.	90 of feed oil
(2) Solids	80	20 (<10% oil)	—	E.D.	90-98 of feed solids
(3) Water	<50 ppm		—	P.R.	

*Destination Designation (DD):

ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: 350Kpa (Identify Pressure Level) for heating
Hot water or Condensate: NO (YES or NO)
Utility Water & Cooling Water: Yes (YES or NO) OR,
Potable or Demin Water: YES (YES or NO)
Fuel: NO (Identify fuel types)
Chemicals: Treating Chemicals (Provide generic names)
Blanketing Gas: NO (Identify the gas, if YES)
Others: — (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES ___ (P/l provide info below)
Patent Number(s): Can. pat. Nos: 1237629 & 1234888, other is currently applied in U.S. & Can
Country(ies) & Date(s):

2. Development Status The O.S.SEP. process combines technologies developed since 1983 with recent 1989 developments.

Bench-Scale Test Completion Date:
Demonstration Test 1984 - 10 L/Min and 1989 -
Size of Unit: _____ (GPM, L/Hr, T/D, etc.) 600 L batch, processed at 60
Test Sites or Feed Sources: Syncrude tailings, B.P. Wolf Lake, Shell prac-
Modifications or Improvements Needed: _____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

The Process uses commercially available equipment (mixing tanks, separators and non-toxic chemicals.

III COST DATA

1. Costing Base $50/1000 KWh

a. Size of Unit on which cost estimate is based: 5 T/Hr
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity 50/1000 KWh, NG 2.6, Fuel Oil —
Coal —, Steam $7, Others _____
d. Operating Labour Rate(s): $19/Hr
e. Capitalization: 25 years on 10% Interest Rate

/1000 Kg /1000 C.F.

2. Capital Installation Cost: $ 0.9 M
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $0.72M/year on Capacity Factor 32 % (seasonal work!)

b. Breakdown

	$ \times 10^6$
Capitalization :	0.100
Operating Labour :	0.315
Chemicals & Consumables :	0.021
Utilities :	0.010
Maintenance & Replacement :	0.225 (pilot operation!)
~~Treated~~ Streams Disposal :	N/A (included in operating labour & rentals)
Rentals :	0.050

IV DESIGN DOCUMENTS

Please check and include available documents:

☑ : Process Flow Diagram (PFD)

☑ : Material Balance

} will be provided in later date.

☐ : Utility Flow Diagram (UFD) & Utility Balance

☐ : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

☐ : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

☐ : Others, please specify: _____

_____

Engineering design work is in progress.

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

STS Solids Treatment System

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: Alberta Solids Treatment Corp. Ltd.
Contact Person: Dave Hull **Title:** Managing Director
Address: Taber

Telephone: (403) 223-9082 **Telefax:** (403) 223-9082

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:** Solids Treatment Systems uses a Multi-Hopper, Gravity Separation with Screen Conveyor, Four Cyclone and Vibrating Solids Screening System

2. **Feed Specifications & Constraints**

Solids (%):	60	(normal)	0	(minimum)	85	(maximum)
Oil (%):	15	(")	10	(")	50	(")
Water (%):	15	(")	0	(")	35	(")

Any Constraint in Feed? Maximum Size Solids 3"

3. **Please Identify Four Key Process Sub-systems.**

	Sub-systems	Operating Pressure	Operating Temperature
a.		ATM	165 - 200 °F
b.			
c.			
d.			

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Solids				FT	
Water				FT	
Oil				PR	

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: Yes (Identify Pressure Level) 3 million BTU/hr
Hot water or Condensate: No (YES or NO)
Utility Water & Cooling Water: No (YES or NO)
Potable or Demin Water: No (YES or NO)
Fuel: Natural Gas (Identify fuel types)
Chemicals: OPTIONAL (Provide generic names)
Blanketing Gas: No (Identify the gas, if YES)
Others: _____ (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ✓ YES ___ (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date: 1985
Demonstration Test
Size of Unit: 5 (GPM, L/Hr, T/D, etc.) m^3/hr.
Test Sites or Feed Sources: Hydrocarbon contaminated solids
Modifications or Improvements Needed: _____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: 5 m^3/hr
b. Base year: Please base it on 1990 application year. 1990
c. Utility Rates: Electricity *, NG **, Fuel Oil ___ * $3.88/hr
Coal ___, Steam ___, Others _____ * $7.44/hr
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $ 600,000.00
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____%
b. Breakdown
Capitalization :
Operating Labour :
Chemicals & Consumables :
Utilities :
Maintenance & Replacement :
Treated Streams Disposal :

IV DESIGN DOCUMENTS

Please check and include available documents:

☐ : Process Flow Diagram (PFD)

☐ : Material Balance

☐ : Utility Flow Diagram (UFD) & Utility Balance

☐ : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

☐ : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

☐ : Others, please specify: _____

_____

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

"Oily Sand By-product Road Surfacing"
(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: Esso Resources Canada Ltd.
Contact Person: Dave Price Title: Assistant Contract Planner
Address: Servis Bag 15
GRAND CENTER, AB T0A 1T0
Telephone: (403) 639-5311 Telefax: (403) 639 5365

I TECHNOLOGY DEFINITION

1. Concise Description of the Technology: Reservoir sand with entrained bitumen is mixed with gravel, then applied to roads to make a solid, all weather road surface

2. Feed Specifications & Constraints

		(normal)		(minimum)		(maximum)
Solids (%):	80	( )		( )		( )
Oil (%):	13	( )	10	( )	20	( )
Water (%):	7	( )	5	( )	15	( )

10 gravel addition

Any Constraint in Feed? desirable to reduce water content as much as possible

3. Please Identify Four Key Process Sub-systems.

	Sub-systems	Operating Pressure	Operating Temperature
a.	front end loade	, dump trucks,	various road surface
b.	"packers"	graders &	mixers
c.			
d.			

4. Product Streams Description

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
item 2	+ gravel,	1:1	(more or	less)	ratio

↳ destination → roads.

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: NO (Identify Pressure Level)
Hot water or Condensate: NO (YES or NO)
Utility Water & Cooling Water: YES (YES or NO) - clean up of equipment
Potable or Demin Water: NO (YES or NO)
Fuel: YES (Identify fuel types) to run equipment
Chemicals: NO (Provide generic names)
Blanketing Gas: NO (Identify the gas, if YES)
Others: _____ (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ✓ YES ___ (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: _____ (GPM, L/Hr, T/D, etc.)
Test Sites or Feed Sources: _____
Modifications or Improvements Needed: _____

✓ Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information. → see paper (attached)
used on roads at ERCL's Cold Lake site

Other Information Relevant to Availability of the Technology:

attached paper details process & results.

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: ≥ 4-6000 m^3/year of oily sand.
b. Base year: Please base it on 1990 application year. ✓
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others _____
d. Operating Labour Rate(s): ≥ $70/m3 (see attached detail)
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $ none
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____%

b. Breakdown

Capitalization	:	see attached.
Operating Labour	:	
Chemicals & Consumables	:	
Utilities	:	
Maintenance & Replacement	:	
Treated Streams Disposal	:	

IV DESIGN DOCUMENTS

Please check and include available documents:

☐ : Process Flow Diagram (PFD)

☐ : Material Balance

☐ : Utility Flow Diagram (UFD) & Utility Balance

☐ : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

☐ : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

☑ : Others, please specify: See attached paper

_____

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

Fujibeton

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: Canadian Waste Management Ltd.
Contact Person: W. (Bill) Rama **Title:** Project Manager
Address: #205 - 2003 McKnight Blvd. NE, Calgary, Alberta T2E 6L2

Telephone: (403) 291-5082 **Telefax:** (403) 291-5084

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:** Polymer additive to normal Portland 10 cement. Used to micrencapsulate metals and some organic compounds in concrete.

2. **Feed Specifications & Constraints**

Solids (%):	80	(normal)	10	(minimum)	100	(maximum)
Oil (%):	10	( )	5	( )	15	( )
Water (%):	10	( )	10	( )	100	( )

Any Constraint in Feed? Particle sizes less than 500 mm are desirable.

3. **Please Identify Four Key Process Sub-systems.**

	Sub-systems	Operating Pressure	Operating Temperature
a.	Mixing	Ambient	Ambient
b.	Pouring	Ambient	Ambient
c.	Curing	Ambient	Ambient
d.			

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
'Concrete'	100	* 0	0	ED	105

* After Curing.

CWM

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: No (Identify Pressure Level)
Hot water or Condensate: No (YES or NO)
Utility Water & Cooling Water: Yes (YES or NO)
Potable or Demin Water: No (YES or NO)
Fuel: No (Identify fuel types)
Chemicals: Portland 10 cement (Provide generic names)
Blanketing Gas: No (Identify the gas, if YES)
Others: _____ (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO x YES ___ (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s):
Proprietary formulas held by manufacturer in Japan.

2. Development Status

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: _____ (GPM, L/Hr, T/D, etc.)
Test Sites or Feed Sources: _____
Modifications or Improvements Needed: _____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

In commercial use in Japan for 15 years. First commercial application scheduled for Alberta in Spring of 1990.

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: N/A
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___, Coal ___, Steam ___, Others _____) Alberta Market Rates
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

CW

2. Capital Installation Cost: $ No Capital Cost
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____%

b. Breakdown

Capitalization	:	Varies with site and waste quantities. Field application of this treatment process uses conventional concrete making technology.
Operating Labour	:	
Chemicals & Consumables	:	
Utilities	:	
Maintenance & Replacement	:	
Treated Streams Disposal	:	

IV DESIGN DOCUMENTS

Please check and include available documents:

☐ : Process Flow Diagram (PFD)

☐ : Material Balance

☐ : Utility Flow Diagram (UFD) & Utility Balance

☐ : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

☐ : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

☐ : Others, please specify: _____

_____

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

VAM/Chemsafe Process
(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: Canadian Waste Management Ltd./Superburn Systems Ltd
Contact Person: W. (Bill) Rama **Title:** Project Manager
Address: #205 - 2003 McKnight Blvd. NE
Calgary, Alberta T2E 6L2
Telephone: (403) 291-5082 **Telefax:** (403) 291-5084

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:** Fixation by Lime

2. **Feed Specifications & Constraints**

Solids (%):		(normal)	5	(minimum)	100	(maximum)		
Oil (%):		( )	0	( )	95	( )		
Water (%):		( )	0	( )	95	( )		

Any Constraint in Feed? Feed particle size should be less than 8.0 cms.

3. **Please Identify Four Key Process Sub-systems.**

	Sub-systems	Operating Pressure	Operating Temperature
a.	Lime injection	+ 10 lbs.	Ambient
b.	Reaction Chamber	Ambient	Ambient
c.			
d.			

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Treated Soil	100	0	0	ED	105

CWA

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: No (Identify Pressure Level)
Hot water or Condensate: No (YES or NO)
Utility Water & Cooling Water: No (YES or NO)
Potable or Demin Water: Yes (YES or NO)
Fuel: No (Identify fuel types)
Chemicals: Lime (Provide generic names)
Blanketing Gas: None (Identify the gas, if YES)
Others: _____ (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES x (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s): Patents held by Voest-Alpine Montage, Wels, Austria. These can be made available by special request.
2. Development Status

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: _____ (GPM, L/Hr, T/D, etc.)
Test Sites or Feed Sources: _____
Modifications or Improvements Needed: _____
_____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

In commercial use in Europe for 15 years. First commercial plant being installed in Big Valley, Alberta, in Spring 1990.

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: 20 T P H
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___)
Coal ___, Steam ___, Others _____)Alberta Market
d. Operating Labour Rate(s): $12 - 20 Hr.)Rates
e. Capitalization: 25 years on 10% Interest Rate

C

2. Capital Installation Cost: $ 2.8 Million
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____% $130 - $250/T depending on waste stream characteristics

b. Breakdown

Capitalization	:	
Operating Labour	:)	
Chemicals & Consumables	:)	
Utilities	:)	Varies with site and waste quantities
Maintenance & Replacement	:)	due to transportable design of this
Treated Streams Disposal	:)	equipment.

IV DESIGN DOCUMENTS

Please check and include available documents:

[x] : Process Flow Diagram (PFD)

[ ] : Material Balance

[ ] : Utility Flow Diagram (UFD) & Utility Balance

[ ] : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

[ ] : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

[ ] : Others, please specify: _____

_____

CWh.

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

PRODUCED SAND REPLACEMENT

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: HALLIBURTON SERVICES LTD.
Contact Person: H.E. Ripley Title: Manager Engineering
Address: 1100, 550 - 6th. Ave. S.W.
Calgary, Alberta T2P 0S2
Telephone: (403) 269-6141 Telefax: ( )

I TECHNOLOGY DEFINITION

1. Concise Description of the Technology: Using oilfield hydraulic fracturing technology the slurried oily solids injected into an approved subterranean formation via a conventional oil well.

2. Feed Specifications & Constraints
By Mass:

		(normal)		(minimum)		(maximum)
Solids (%):	50		0		75	
Oil (%):	50	(")	100	(")	25	(")
Water (%):		(")		(")		(")

Any Constraint in Feed? Solids must pass a 10 mesh seive

3. Please Identify Four Key Process Sub-systems.

	Sub-systems	Operating Pressure	Operating Temperature
a.	Storage	Ø	-
b.	Slurring	700 kPa	10 to 30°C
c.	Injection	14 MPa	10 to 30°C
d.			

4. Product Streams Description

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Oily Solids	65	35	Ø	F.T.	50
Water	Ø	100	Ø	ED	50

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: NIL (Identify Pressure Level)
Hot water or Condensate: NO (YES or NO)
Utility Water & Cooling Water: YES (YES or NO)
Potable or Demin Water: NO (YES or NO)
Fuel: Diesel (Identify fuel types)
Chemicals: NIL (Provide generic names)
Blanketing Gas: NIL (Identify the gas, if YES)
Others: NIL (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO * YES ___ (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: _____ (GPM, L/Hr, T/D, etc.)
Test Sites or Feed Sources: _____
Modifications or Improvements Needed: _____
_____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

The injection of sand slurries into rock formation as a stimulation technique has been conducted in Canada for the past 38 years. The injection of waste slurries has also been conducted at various sites.

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based:
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others _____
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

PLEASE REFER TO ATTACHMENT.

Halliburton would be prepared to provide the necessary mixing, pumping, and piping systems to slurry and raise the pressure of the slurry to injection pressure on a call out basis for a contract price as follows:

EQUIPMENT SUPPLIED BY HALLIBURTON:

1) Blending/Mixing Unit

2) Centifugal Transfer Pump

3) Temporary Piping and Hoses

4) Pressure Intensifier

5) Pressure and Flow-Rate Monitors

6) Engineering and Supervision

EQUIPMENT AND SUPPLIES BY OTHERS:

1) Water in Storage tanks

2) "Oily Solids" storage facility

3) Transfer apparatus to move "Oily Solids" from storage to Halliburton mixer.

4) Suitable disposal well and work site

We estimate that 250 m3 of "Oily Solids" can be injected in one ten hour period.

Halliburton's charge would be approximately $75.00 to $100.00 per cubic metre of oily solids based on a 250 m3 batch.

This type of disposal has successfully been performed in the past with very little pre job organization.

With industry financing assurance, Halliburton is capable of contributing expertise to the mixing, pumping and disposal by injection of oily solids waste.

We hope to hear from you in the future.

HR/df

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

" SESA "

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: TERRA ENERGY LTD.
Contact Person: DR. G.W GOVIER Title: CONSULTANT
Address:
1507 CAVANAUGH PL. N.W. CALGARY T2L0M8
Telephone: (403) 282 2964 Telefax: (403) 2849597

I TECHNOLOGY DEFINITION

1. Concise Description of the Technology: SOLVENT EXTRACTION INCORPORATING SPHERICAL AGGLOMERATION

2. Feed Specifications & Constraints

Solids (%):	43	(normal)	44	(minimum)	72	(maximum)
Oil (%):	12	(✓)	1	( )	20	( )
Water (%):	5	(✓)	3	( )	9	( )

Any Constraint in Feed? MIGHT CONTAIN SOME FINE SOLIDS IN CLAY RANGE

3. Please Identify Four Key Process Sub-systems.

Sub-systems	Operating Pressure	Operating Temperature
a. CONTACTING	ATMOS	50°C
b. FILTERING	VACUUM	45°C
c. SOLVENT RECOVERY	ATMOS	100°C
d. DISTILLATION	ATMOS	190°C

4. Product Streams Description

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: 50 PSIG (Identify Pressure Level)
Hot water or Condensate: YES (YES or NO)
Utility Water & Cooling Water: YES (YES or NO)
Potable or Demin Water: NO (YES or NO)
Fuel: GAS (Identify fuel types)
Chemicals: NO (Provide generic names)
Blanketing Gas: NITROGEN (Identify the gas, if YES)
Others: NAPHTHA SOLVENT (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES ___ (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date: SPRING 1991
Demonstration Test
Size of Unit: 10 (GPM, L/Hr, T/D, etc.) t/d
Test Sites or Feed Sources: FORT MC. MURRAY
Modifications or Improvements Needed: TO BE CONSIDERED

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based:
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others ___
d. Operating Labour Rate(s): ___
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $_____
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____%
b. Breakdown

Capitalization	:
Operating Labour	:
Chemicals & Consumables	:
Utilities	:
Maintenance & Replacement	:
Treated Streams Disposal	:

IV DESIGN DOCUMENTS

Please check and include available documents:

☐ : Process Flow Diagram (PFD)

☐ : Material Balance

☐ : Utility Flow Diagram (UFD) & Utility Balance

☐ : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____
_____

☐ : Utility P&ID's or MFD's, giving a list of Titles & Numbers:
_____
_____

☐ : Others, please specify: _____
_____

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

" RTR / GULF SLUDGE TREATMENT "

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: RTR OIL SANDS (Alberta) Ltd
Contact Person: A. CORTI Title: V.P
Address: 22200 - 401 - 9R Ave S.W CALGARY, ALTA T2P 4J5
Telephone: (403) 233-3482 Telefax: (403) 233-5143

I TECHNOLOGY DEFINITION

1. Concise Description of the Technology: Feed Conditioning by dilution + chemicals addition followed by phase separations.

2. Feed Specifications & Constraints

Solids (%):	25	(normal)	N/A	(minimum)	35	(maximum)
Oil (%):	20	( )	N/A	( )	45	( )
Water (%):	55	( )	-	( )	20	( )

Any Constraint in Feed? MUST BE PUMPABLE

3. Please Identify Four Key Process Sub-systems.

	Sub-systems	Operating Pressure	Operating Temperature
a.	CONDITIONING	ATM	40 - 80
b.	PHASE SEPARATION	ATM	40 - 80
c.	OIL CLEAN-UP	ATM - 50 PSI	70 - 120
d.			

4. Product Streams Description

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
SOLID PHASE	55-75	45-25	-	ED-FT	*
WATER PHASE	1	99	-	PR	*
OIL PHASE	0.5	99.5	-	PR	*

* FUNCTION OF FEED COMPOSITION

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: 50 PSI (Identify Pressure Level)
Hot water or Condensate: NO (YES or NO)
Utility Water & Cooling Water: NO (YES or NO)
Potable or Demin Water: NO (YES or NO)
Fuel: NG (Identify fuel types)
Chemicals: DEMULSIFIER (Provide generic names)
Blanketing Gas: NITROGEN (Identify the gas, if YES)
Others: _____ (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES ___ (P/l provide info below)
Patent Number(s): PATENT APPLICATION FILED IN U.S & CANADA
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: 100 (GPM, (L/Hr), T/D, etc.)
Test Sites or Feed Sources: GULF PELICAN LAKE SLUDGE
Modifications or Improvements Needed: _____
CHEMICAL SCREENING

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

_____
_____

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: 20,000 bbl/year sludge
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity (1), NG (2), Fuel Oil —
Coal --, Steam (2), Others _____
d. Operating Labour Rate(s): 20 $/hr
e. Capitalization: 25 years on 10% Interest Rate

(1) 3.85 ¢/KWh
(2) 2.36 ¢/1000 K cal

2. Capital Installation Cost: $ 540,000 DIRECT FIELD COSTS
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ 200,000 /year on Capacity Factor 50 %

b. Breakdown

Capitalization	:	110 000 *
Operating Labour	:	43,000
Chemicals & Consumables	:	7,620
Utilities	:	7,380
Maintenance & Replacement	:	36,288
Treated Streams Disposal	:	69,200

(1)

IV DESIGN DOCUMENTS

Please check and include available documents:

[ ] : Process Flow Diagram (PFD)

[x] : Material Balance

[ ] : Utility Flow Diagram (UFD) & Utility Balance

[ ] : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

[ ] : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

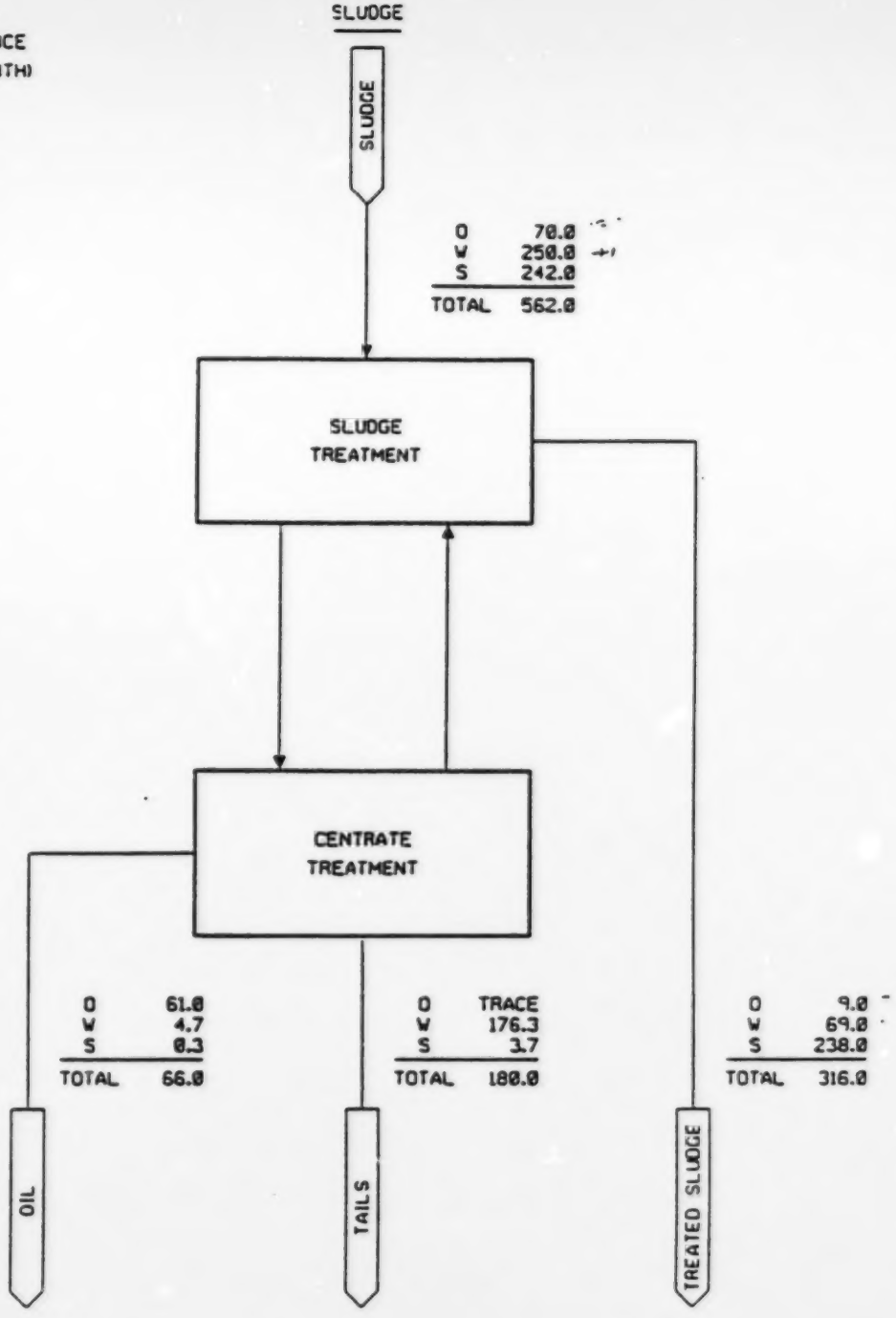
[ ] : Others, please specify: _____

_____

(1) Revenue from oil recovered ≃ 68,400 $/y

* Include Treated stream Disposal Installation.

MASS BALANCE
(TONNES/MONTH)



GULF CANADA RESOURCES INC.

PELICAN SLUDGE
RTR TREATMENT
MASS BALANCE

PELICAN ALBERTA

DATE 85/09/30

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

FLUID BED COMBUSTION

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: PACIFIC ENVIRONMENT SYSTEMS INC.
Contact Person: BRYAN G. SCOTT **Title:** PRESIDENT
Address: 520, 1502 Centre St S Calgary, Alberta T2G 2E6
Telephone: (403) 234-9622 **Telefax:** (403) 266-1670

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:**
Combustion with sand fluid media and temperature control to minimize NOx emission.

2. **Feed Specifications & Constraints**

Solids (%):	-	(normal)	-	(minimum)	-	(maximum)
Oil (%):	-	(")	15	(")	-	(")
Water (%):	-	(")	-	(")	-	(")

Any Constraint in Feed? Minimum feed 2500 BTU/lb LHV.
Maximum particle / feed size 3"

3. **Please Identify Four Key Process Sub-systems.**

	Sub-systems	Operating Pressure	Operating Temperature
a.	Fluid Bed		600 - 750 °F
b.	Combustion Chamber		
c.	Cyclone (Filter)		
d.			

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
SAND	100	0	0	ED	
ASH	100	0	0	ET	
GAS	0	-	100	ED	
THERMAL ENERGY	-	-	-	PE	

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: NO (Identify Pressure Level)
Hot water or Condensate: NO (YES or NO)
Utility Water & Cooling Water: YES (YES or NO)
Potable or Demin Water: YES (YES or NO)
Fuel: Natural Gas (Identify fuel types)
Chemicals: No (Provide generic names)
Blanketing Gas: NO (Identify the gas, if YES)
Others: Electricity (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES ___ (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date: 1984/09/19
Demonstration Test
Size of Unit: 395 (GPM, L/Hr, T/D, etc.) lb/hr.
Test Sites or Feed Sources: EPI Plant with Oil clay feed
Modifications or Improvements Needed: _____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: 10 m³/hr
b. Base year: Please base it on 1990 application year. 1990/07/01.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others _____
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $ 4,387,500.00
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs
800,000.00 - 1,000,000.00
a. $ /year on Capacity Factor _____%
b. Breakdown
Capitalization :
Operating Labour :
Chemicals & Consumables :
Utilities :
Maintenance & Replacement :
Treated Streams Disposal :

IV DESIGN DOCUMENTS

Please check and include available documents:

[ ] : Process Flow Diagram (PFD)

[ ] : Material Balance

[ ] : Utility Flow Diagram (UFD) & Utility Balance

[ ] : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

[-] : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

[ ] : Others, please specify: _____

_____

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

VOLATILATOR PROCESS

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: Enachem a Solvents Limited
Contact Person: D Keith Jackson **Title:**
Address: 26 Sagewood Drive, Don Mills Ontario M3B 2G5

Telephone: (416) 441 - 2651 **Telefax:** ( )

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:** Incineration of spent wash still bottom sludge and solvent laden water which was sprayed fed to the pyrolizing reactor

2. **Feed Specifications & Constraints**

	Resin		25			40		
Solids (%):		(normal)	5	(minimum)		10	(maximum)	
Solvent ~~Oil~~ **(%):**	50	(")		(")			(")	
Water (%):		(")	5	(")		20	(")	

Any Constraint in Feed?

3. **Please Identify Four Key Process Sub-systems.**

	Sub-systems	Operating Pressure	Operating Temperature
a.	Blender - Flasher	Atm	
b.	Reactor & Cyclones	Atm	
c.	Solvent recovery		
d.	After Burner		>980 °C
	Baghouse		~205 °C

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Solvent		100		PR	0.2 %
Ash	100			ED	0.4 %
Flue Gas			100 %	ED	99.31 %
Thermal Energy				PR	

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: No (Identify Pressure Level)
Hot water or Condensate: No (YES or NO)
Utility Water & Cooling Water: Yes (YES or NO)
Potable or Demin Water: No (YES or NO)
Fuel: Fuel Oil # 2 (Identify fuel types)
Chemicals: No (Provide generic names)
Blanketing Gas: No (Identify the gas, if YES)
Others: No (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES ✓ (P/l provide info below)
Patent Number(s): Not Submitted
Country(ies) & Date(s): Not Submitted

2. Development Status

Bench-Scale Test Completion Date: 1986/12/15-23
Demonstration Test
Size of Unit: 246 (GPM, L/Hr, T/D, etc.) ton/hr.
Test Sites or Feed Sources: Solvent contained waste
Modifications or Improvements Needed: _____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: Not Submitted
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others _____
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $_____
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____%
b. Breakdown

Capitalization	:
Operating Labour	:
Chemicals & Consumables	:
Utilities	:
Maintenance & Replacement	:
Treated Streams Disposal	:

IV DESIGN DOCUMENTS

Please check and include available documents:

☐ : Process Flow Diagram (PFD)

☐ : Material Balance

☐ : Utility Flow Diagram (UFD) & Utility Balance

☐ : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____
_____

☐ : Utility P&ID's or MFD's, giving a list of Titles & Numbers:
_____
_____

☐ : Others, please specify: _____
_____

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

DOLEN BURNER.

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: Environment Protection Company Inc
Contact Person: Allan P Salmon **Title:** CEO
Address: #8N 7205 - 4th Street NE, Calgary, T2K 5S3

Telephone: (403) 275-2515 **Telefax:** ( )

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:**
Combustion of oil contaminated wastes by burning in open flame

2. **Feed Specifications & Constraints**

Solids (%):	N.A	(normal)		(minimum)			(maximum)	
Oil (%):	N.A	(")		(")			(")	
Water (%):	N.A	(")		(")			(")	

Any Constraint in Feed?

3. **Please Identify Four Key Process Sub-systems.**

Sub-systems	Operating Pressure	Operating Temperature
a. Propane Burners		
b. Rotating Drum		
c. Fabric Bag House		
d. Afterburner		

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Burned Solids	99.5	0.5		FT	
Gases			100		
Ash				FT	

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: No (Identify Pressure Level)
Hot water or Condensate: No (YES or NO)
Utility Water & Cooling Water: No (YES or NO)
Potable or Demin Water: No (YES or NO)
Fuel: Propane (Identify fuel types)
Chemicals: No (Provide generic names)
Blanketing Gas: No (Identify the gas, if YES)
Others: No (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ✓ YES ___ (P/l provide info below)
Patent Number(s):
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: _____ (GPM, L/Hr, T/D, etc.) Not Submitted
Test Sites or Feed Sources: _____
Modifications or Improvements Needed: _____
_____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

_____
_____

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: Not Submitted
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others _____
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $_____ Not Submitted
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____%

b. Breakdown

Capitalization	:	$ 50.00 - $ 100.00 /tonne
Operating Labour	:	
Chemicals & Consumables	:	
Utilities	:	
Maintenance & Replacement	:	
Treated Streams Disposal	:	

IV DESIGN DOCUMENTS

Please check and include available documents:

☐ : Process Flow Diagram (PFD)

☐ : Material Balance

☐ : Utility Flow Diagram (UFD) & Utility Balance

☐ : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

☐ : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

☐ : Others, please specify: _____

_____

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

LURGI FLASHPYRO PROCESS

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: Lurgi Canada Ltd
Contact Person: Richard F Doyle **Title:** President
Address: 100 Adelaide St West Toronto M5H 1S3
Telephone: (416) 366-5611 **Telefax:** ( )

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:** Heat transfer to feed material by a solid heat carrier produced in the process

2. **Feed Specifications & Constraints**

Solids (%):	_____	(normal)	68.3	(minimum)	91.3	(maximum)
Oil (%):	_____	(")	5.1	(")	13.4	(")
Water (%):	_____	(")	2.3	(")	13.1	(")

Any Constraint in Feed? _____

3. **Please Identify Four Key Process Sub-systems.**

Sub-systems	Operating Pressure	Operating Temperature
a. Lift Pipe		
b. Collecting Bin		600°C.
c. Mixer		515 - 542°C.
d. Swept Prim. Cyclone		

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Heavy Oil				PR	7.9 - 61
Middle Oil				PR	1.9 - 14.8
Gas Naphtha				PR	0.2 - 2.1
Gas Liquor				PR	3.1 - 5
GAD					0.8 - 10.1
Residue				FT	1.15 - 86.1

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: No (Identify Pressure Level)
Hot water or Condensate: No (YES or NO)
Utility Water & Cooling Water: Yes (YES or NO)
Potable or Demin Water: No (YES or NO)
Fuel: _____ (Identify fuel types)
Chemicals: _____ (Provide generic names)
Blanketing Gas: _____ (Identify the gas, if YES)
Others: _____ (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ✓ YES ___ (P/l provide info below)
Patent Number(s): Not Submitted
Country(ies) & Date(s): Not Submitted

2. Development Status

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: 223 (GPM, L/Hr, T/D, etc.) kg/hr
Test Sites or Feed Sources: Athabasca Tar Sand
Modifications or Improvements Needed: _____

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: Not Submitted
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___
Coal ___, Steam ___, Others _____
d. Operating Labour Rate(s): _____
e. Capitalization: 25 years on 10% Interest Rate

2. Capital Installation Cost: $_____ Not Furnished
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs

a. $ /year on Capacity Factor _____% Not Furnished
b. Breakdown

Capitalization	:
Operating Labour	:
Chemicals & Consumables	:
Utilities	:
Maintenance & Replacement	:
Treated Streams Disposal	:

IV DESIGN DOCUMENTS

Please check and include available documents:

[✓] : Process Flow Diagram (PFD)

[✓] : Material Balance

[✓] : Utility Flow Diagram (UFD) & Utility Balance

[ ] : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

[ ] : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

[ ] : Others, please specify: _____

_____

OIL WASTES CLEANUP TECHNOLOGY

INFORMATION SUMMARY

" "

Revolving Fluidized Bed Incinerator

(PROCESS/TECHNOLOGY TRADE NAME)

Proponent Company: Superburn Systems Ltd.
Contact Person: W. (Bill) Rama **Title:** Project Manager
Address: #205 - 2003 McKnight Blvd. NE, Calgary, Alberta T2E 6L2

Telephone: (403) 291-5082 **Telefax:** (403) 291-5084

I TECHNOLOGY DEFINITION

1. **Concise Description of the Technology:** A sand bed fluidized by injection of excess air.

2. **Feed Specifications & Constraints**

Solids (%):	_____	(normal)	0	(minimum)	100	(maximum)
Oil (%):	_____	(")	0	(")	100	(")
Water (%):	_____	(")	0	(")	100	(")

Any Constraint in Feed? Solids must be less than 12 x 12 x 12 cms in size. Auxiliary fuel required for low Btu feed.

3. **Please Identify Four Key Process Sub-systems.**

Sub-systems	Operating Pressure	Operating Temperature
a. Solid Feed	0 - 5 lbs.	Ambient
b. Liquid Feed	0 - 5 bls.	Ambient
c. Furnace	Ambient	Up to 1050°C
d. Baghouse	0.012 q	Up to 350°C

4. **Product Streams Description**

Streams Name	Solids %	Liquid %	Gas %	DD*	As % Feed
Bottom Ash	100	0	0	ED	40
Cyclone Ash	100	0	0	ED	45
Baghouse Ash	100	0	0	ED	15

CWN

*Destination Designation (DD):
ED: Environmental Disposal without further treatment
FT: Further Treatment required
PR: Process Reusable

5. External Utilities Requirements

Steam: None (Identify Pressure Level)
Hot water or Condensate: No (YES or NO)
Utility Water & Cooling Water: Yes (YES or NO)
Potable or Demin Water: Yes (YES or NO)
Fuel: Diesel/Propane/NG (Identify fuel types)
Chemicals: No (Provide generic names)
Blanketing Gas: No (Identify the gas, if YES)
Others: _____ (Excluding plant air & electricity)

II TECHNOLOGY REGISTRATION & DEVELOPMENT STATUS

1. Registration: NO ___ YES ___ (P/l provide info below)
Patent Number(s): See Attached Appendix 1
Country(ies) & Date(s):

2. Development Status

Bench-Scale Test Completion Date:
Demonstration Test
Size of Unit: 10 TPH (GPM, L/Hr, T/D, etc.)
Test Sites or Feed Sources: _____
Modifications or Improvements Needed: _____
None for oily sand

Commercial Application: Please provide your clients/sites, unit sizes, dates of application, and other information.

Other Information Relevant to Availability of the Technology:

This equipment is in commercial use in Japan, Britain, Germany and will start up at Sysco Steel Works in Nova Scotia in the fall of 1990. 10 T/hr. soils remediation unit to start up at Big Valley, Alberta fall/winter 1990.

III COST DATA

1. Costing Base

a. Size of Unit on which cost estimate is based: 10 T P H
b. Base year: Please base it on 1990 application year.
c. Utility Rates: Electricity ___, NG ___, Fuel Oil ___, Coal ___, Steam ___, Others _____) Alberta Mark Rates
d. Operating Labour Rate(s): $12 - $20/Hr.
e. Capitalization: 25 years on 10% Interest Rate

CW

2. Capital Installation Cost: $ 3.8 Million
(Excluding: Royalty, Engineering License Fee & Engineering Service Fees)

3. Operating Costs
$130 - $250/T dependent on waste stream characteristics.
a. $ /year on Capacity Factor _____%
b. Breakdown

Capitalization	:	
Operating Labour	:	Varies with site and quantities due to
Chemicals & Consumables	:	transportable design of this equipment.
Utilities	:	
Maintenance & Replacement	:	
Treated Streams Disposal	:	

IV DESIGN DOCUMENTS

Please check and include available documents:

[x] : Process Flow Diagram (PFD)

[ ] : Material Balance

[ ] : Utility Flow Diagram (UFD) & Utility Balance

[ ] : Piping & Instrument Diagrams (P&ID) or Mechanical Flow Diagrams (MFD), giving a list of Titles & Numbers: _____

_____

[ ] : Utility P&ID's or MFD's, giving a list of Titles & Numbers:

_____

_____

[ ] : Others, please specify: _____

_____

CWM

Appendix 1

Superburn Systems Ltd. Patents -

Registered in Own Name

Canada	9.52.695
U.S.A.	4.249.472 3.577.938 3.577.939 3.702.595 3.921.590 3.745.940
Argentina	191 368
Brazil	P17108107

APPENDIX D

INVITATION PACKAGE FOR FIELD TESTING AND ASSESSMENT

Monenco
Engineering a whole new world.

1990-03-20
CPA 8601-2

Mr. Harry Ripley
Halliburton Services Ltd.
1100, 550 - 6th Avenue S.W.
Calgary, Alberta
T2P 0S2

Dear Harry:

RE: **Evaluation of Produced Oily Solids Cleanup Technologies**
CPA File: AFE 89-6205-036

I am pleased to inform you that Re-injection Technology has been selected for a detailed assessment for field testing. Being recognized by the CPA Project team as one of the three best technologies out of the thirty six contenders is indeed a remarkable achievement - our congratulations!

In the following four to six weeks, we would carry out a more detailed assessment for the three selected technologies to:

o ascertain definitive design and cost data, and

o define the scope and cost of a field testing program.

Upon completion of the assessment, we would recommend to CPA A TECHNOLOGY - or two technologies, if compelling reasons exist - FOR FIELD TESTING.

.../2

Monenco Consultants Limited
400 Monenco Place
801 - 6th Avenue S.W., Calgary
Alberta, Canada T2P 3W3
Telex: 03-822636 MON CGY
Fax: (403) 298-4125
Telephone: (403) 298-4170

The essential data or documents are identified in the attached "Information Required for Detailed Assessment". We would appreciate receiving them by April 2, 1990. A discussion meeting with you or your company representatives is scheduled for April 4 (Wednesday), 9 AM - 11:30 AM at our office (Monenco Place, 801 - 6th Avenue S.W., Calgary).

Should you have questions, please do not hesitate to contact me at 298-4563.

Your continuing cooperation is appreciated.

Yours truly,

Frank H. Wu
Project Manager

FHW:mvw
Attach.

Monenco
Engineering a whole new world.

1990-03-20
CPA 8601-2

Mr. Ron Souther
ASTCO Ltd.
Box 235
Barnwell, Alberta
T0K 0B0

Dear Ron:

RE: Evaluation of Produced Oily Solids Cleanup Technologies
CPA File: AFE 89-6205-036

I am pleased to inform you that STS Technology has been selected for a detailed assessment for field testing. Being recognized by the CPA Project team as one of the three best technologies out of the thirty six contenders is indeed a remarkable achievement - our congratulations!

In the following four to six weeks, we would carry out a more detailed assessment for the three selected technologies to:

- o ascertain definitive design and cost data, and
- o define the scope and cost of a field testing program.

Upon completion of the assessment, we would recommend to CPA A TECHNOLOGY - or two technologies, if compelling reasons exist - FOR FIELD TESTING.

.../2

Monenco Consultants Limited
400 Monenco Place
801 - 6th Avenue S.W. Calgary
Alberta, Canada T2P 3W3
Telex: 03-822636 MON CGY
Fax: (403) 298-4125
Telephone: (403) 298-4170

The essential data or documents are identified in the attached "Information Required for Detailed Assessment". We would appreciate receiving them by April 2, 1990. A discussion meeting with you or your company representatives is scheduled for April 4 (Wednesday), 1:30 PM - 4:00 PM at our office (Monenco Place, 801 - 6th Avenue S.W., Calgary).

Should you have questions, please do not hesitate to contact me at 298-4563.

Your continuing cooperation is appreciated.

Yours truly,

Frank H. Wu
Project Manager

FHW:mvw
Attach.

Monenco
Engineering a whole new world.

1990-03-20
CPA 8601-2

Mr. Bryan G. Scott, President
Pacific Environment Systems Inc.
Center 15, Suite 520
1509 Centre Street S.
Calgary, Alberta
T2G 2E6

Dear Bryan:

RE: Evaluation of Produced Oily Solids Cleanup Technologies
CPA File: AFE 89-6205-036

I am pleased to inform you that Fluid Bed Combustion System has been selected for a detailed assessment for field testing. Being recognized by the CPA Project team as one of the three best technologies out of the thirty six contenders is indeed a remarkable achievement - our congratulations!

In the following four to six weeks, we would carry out a more detailed assessment for the three selected technologies to:

o ascertain definitive design and cost data, and

o define the scope and cost of a field testing program.

Upon completion of the assessment, we would recommend to CPA A TECHNOLOGY - or two technologies, if compelling reasons exist - FOR FIELD TESTING.

.../2

Monenco Consultants Limited
400 Monenco Place
801 - 6th Avenue S.W., Calgary
Alberta, Canada T2P 3W3
Telex: 03-822636 MON CGY
Fax: (403) 298-4125
Telephone: (403) 298-4170

The essential data or documents are identified in the attached "Information Required for Detailed Assessment". We would appreciate receiving them by April 2, 1990. A discussion meeting with you or your company representatives is scheduled for April 5 (Thursday), 1:30 PM - 4:30 PM at our office (Monenco Place, 801 - 6th Avenue S.W., Calgary).

Should you have questions, please do not hesitate to contact me at 298-4563.

Your continuing cooperation is appreciated.

Yours truly,

Frank H. Wu
Project Manager

FHW:mvw
Attach.

1990-03-21

INFORMATION REQUIRED FOR DETAILED ASSESSMENT
CPA 8601-2

I. GENERIC PROCESS DESIGN INFORMATION

2. Design Base Documents

- o Process & mechanical system design basis
- o Electrical classification (e.g. NFPA, Class I, Div. 1, etc.)
- o Mechanical & Piping design code (ASME VIII, ANSI B.31, etc.)
- o Constraints/Limitations - Feeds, Materials of construction, etc.

Process Flow Diagrams/Sketches c/w material balance and utilities balance (water, electrical power, steam, plant air, instrument air, chemicals, etc.) would be required!

2. Engineering Design Information

- o Piping & Instrumentation Diagrams (P&ID's) showing mechanical systems, control, piping etc.
- o Equipment List which compiles equipment, description, basic design & operating data & other essential information
- o Safety design features.

3. Cost Data

Please provide the data of capital and operating costs of a generic unit specified in 1. and 2. above. If the data submitted to Monenco remains valid and requires no supplement, please state so.

II. FIELD TEST FACILITY

Please recommend a test unit size (m^3/hr), if it is different from the available Test Unit to be provided for actual field testing.

1. Test Unit Technical Data

- o Feed or processing capacity (range) & product rates
- o Feed specifications (range) & product spec's
- o Equipment Lists for each and all skids/modules
- o Dimensions and weights of skids (each and all)
- o Auxiliary & temporary facilities required for field test

- o Material handling equipment required, which are NOT to be provided by you
- o Layout Plans/General Arrangement or equivalent drawing(s) SHOWING
  - skid edges
  - all the battery limits, i.e. piping, electrical and instrumentation connections with the external support sources
- o Other design information relevant to outdoor operation.

2. Field Operation

- o Number of operators required for the operation
- o Special qualifications, if any, of the operators
- o Operating procedures - outline - covering
  - pre-startup check out
  - startup
  - normal operation (steady state)
  - rundown and shutdown
- o Safety measures
  - over pressure and temperature protections and other health and safety protections
  - emergency situations & annunciation
  - emergency shutdown
- o Utilities, chemicals and consumables (types and consumption rates)
- o Electrical requirements (voltage, current, Hz and electrical class)
- o Spares and maintenance requirements.

III. FIELD TEST PROGRAM

1. Tasks & Schedule

Please outline the essential tasks and durations to be carried out in order to fully demonstrate the capability and viability of your technology.

2. Terms & Conditions

ON A PRELIMINARY BASIS, please indicate which items in the following would you be willing to pay for in part or in total:

a. Mobilization of the Test Unit at Owner's Site
b. Transportation of the Test Unit to Test Site
c. Field Set-up and Commissioning
d. Test Runs - Operation of the Unit
e. Sampling & Sample Analysis
f. Mobilization of the Test Unit at the Final Test Site
g. Transportation of the Test Unit to Owner's Site
h. Maintenance & Replacement Work on the Test Unit

i. Chemicals
j. Operating Labour
k. Liability Insurance & WCB
l. Modifications on the Test Unit
m. Disposal of Processed Waste Streams.

Please give a preferred alternative arrangement.

IV. COMMERCIAL APPLICATIONS

Should your technology be adopted for commercial application, what option(s) would you be willing to accept?

a. Own- and - Operate by your company with revenue to you on per m^3 processing charge;

b. Supply a packaged, turn-key process plant to CPA at an agreed cost;

c. Leasing a facility system to CPA user(s):

d. Sell the technology at a Licensing Fee (please indicate the fee and/or fee schedule).